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Study of heave acceleration/velocity control for the surface effect ship.

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Monterey, California. Naval Postgraduate School

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STUDY OF HEAVE ACCELERATION/VELOCITY CONTROL FOR THE SURFACE EFFECT SHIP

U. S. Grant

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

STUDY OF HEAVE ACCELERATION/VELOCITY CONTROL
FOR THE SURFACE EFFECT SHIP

by

U. S. Grant, Jr.

December 1974

Thesis Advisor: G. J. Thaler

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Study of Heave Acceleration/Velocity Control

for the Surface Effect Ship

by

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Captain, United States Marine Corps
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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
December 1974

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Only those who have undertaken a project such as this can truly appreciate the influence that others have on its successful conclusion. With this in mind, the author wishes to first express his most sincere appreciation to Professor George J. Thaler of the Naval Postgraduate School. His knowledge, dedication and patience provided the light by which the author traveled.

A great deal of the author's time and effort was spent in the computer center. Without the continued assistance of all the operators, a study like this could not have been completed. A special "thank you" to E. V. Donnellan (ed), M. Anderson (Andy), and K. Butler (Kris) of the evening shift whose personal interest in each student's needs was combined with friendly banter and a job always well done.

To his wife, Kitten, and his two sons, Michael and Philip, the author expresses his gratitude but his apologies for his long periods of absence and concern with thesis matters when he was at home. Without their long suffering devotion, the educational goals of their husband and father would not have been possible and this thesis written.

I. INTRODUCTION

On some day in the not too distant future, a hostile army has launched a sudden attack, pressing an outmanned but determined NATO force backward toward the ocean. On this same ocean a vast armada covering almost 2000 nautical miles in a single twenty-four hour span races to reinforce them. In the center of this great fleet are huge carriers making the task of launching their aircraft much easier by attaining and holding speeds of over eighty knots. Transports, large landing ships and VSTOL/helicopters carriers all with this same 80 knot capability surround the fleet carriers and in turn are screened by the even faster destroyers and destroyer-escorts.

Once off the beach, with Marine and Navy establishing air superiority, some of the large amphibious ships run parallel to the beach discharging smaller craft that turn and head into the shore at seemingly fantastic speeds. Carrying tanks, artillery pieces and other heavy equipment as well as the men of two Marine regiments, these craft race onto the beach and inland before discharging their cargo at strategic points. As they transition from water to sand it can be seen more readily that these craft are not acutally in contact with the beach but hover inches above it as they carry the reinforcements inland.

Quite possibly a glimpse into the future. Perhaps a bit overstated, but if what appears to be the vast potential of the Surface Effect Ship is realizable, a whole new

concept of shipbuilding will take place. One type of SES, the Hovercraft or Ground Effect Machine, GEM, is the subject of a great deal of study by the Marine Corps as its primary ship to shore vehicle of the future. Present day commercial as well as military prototypes are common. The British regularly run "Hovercraft" ferrys across the channel. The GEM, a "fully skirted" craft utilizes reinforced rubberized material in a 360° configuration to confine an air bubble generated by fans or blowers, lifting it above the drag of land or water. This 360° skirt is the basic difference between the GEM and the Captured Air Bubble, CAB, craft, also known by the class name, SES. This skirt permits a steady leakage of air around it and results in an inefficient use of the air flow generated by the fans.

The CAB utilizes the same basic principal as the GEM, but "captures" its "air bubble" by containing it within two rigid sidewalls with flexible seals only at the bow and stern. Instead of riding above the surface as a hovercraft does, the CAB sidewalls travel just beneath the water's surface and except for venting due to wave motion, the air bubble is contained.

Unlike the GEM which because of its inefficient use of its fan flow has size limitations, SES craft have been envisioned as large as fleet type aircraft carriers. While conventional monohulled displacement ships are effectively limited to fifty knots or below because of their (thrust/drag) ratio, the CAB craft takes advantage of the fact that

the greatest part of the gross displacement is due to the pocket of air that forms most of the contact with the water. Drag created by the sidewalls and the bow/stern seals coupled with the drag created by the bubble is much less than for the conventional ship and speeds of greater than eighty knots have been attained.

Presently there are several of these SES-type craft operational. Three of the most interesting are:

1. XR-3 - This craft is located at the Naval Postgraduate School, Monterey, California. Originally built by the David Taylor Model Basin with a displacement of about 2.5 tons, it has undergone modification and instrumentation by Professor D. M. Layton and other members of the staff at the Naval Postgraduate School. Presently it is undergoing testing at Lake San Antonio in southern Monterey County.

2. SES 100-A - Built by Aerojet General Corporation, the SES 100-A underwent initial testing near Tacoma, Washington before being turned over to the Navy for further evaluation. Aeroject General did not receive a contract from the government for further study of a two thousand ton model.

3. SES 100-B - This craft like the 100-A displaces approximately 100 tons and was built by Bell Aerospace Company. After undergoing extensive testing at Lake Pontchatrain, Louisiana where it attained speeds of over 80 knots, it also was turned over to the Navy. Bell was awarded a contract for further study into the building of a two thousand prototype. The 100-B was the subject of a

contract let to Oceanics, Inc. of New York by SESPO, the Surface Effect Ship Project Office in Washington, D. C. They were tasked with developing a computer model of the SES 100-B for simulation studies with the goal of providing a better understanding of the loads and motions of the craft. A copy of this program was made available to the Naval Postgraduate School and was the basic tool used to gather information for this thesis. Modification of this program resulted in a computer model of the XR-3 mentioned above which is undergoing investigation and verification at this time.

II. STATEMENT OF THE PROBLEM

Because the concept of the Captured Air Bubble Craft is fairly new and few actual craft are in existence, the computer has become a primary tool in the study of the CAB's motion and loads under varying circumstances. If the model itself is correct, modifications which would cost many thousands of dollars and a great deal of time can be simulated overnight.

Of primary interest to the author was the design and investigation of an automatic control system to reduce the heave acceleration of the CAB. This was to be coupled with a second control loop to maintain the craft's forward velocity while the heave controller was in operation, and was to be accomplished while maintaining a constant initial thrust by varying only the plenum pressure.

The feasibility of using the plenum pressure for this purpose is suggested by the observation of data from runs using the computer model.

If the model is programmed for two different runs using the same initial conditions for plenum pressure, thrust, draft, and forward velocity, one run to be made under calm water conditions, the other with waves, decreases in forward velocity is accompanied by losses in plenum pressure and a settling of the craft deeper into the water. This is illustrated in Figures 1 and 2 showing the plenum pressure and forward velocity of the SES100-B given the initial

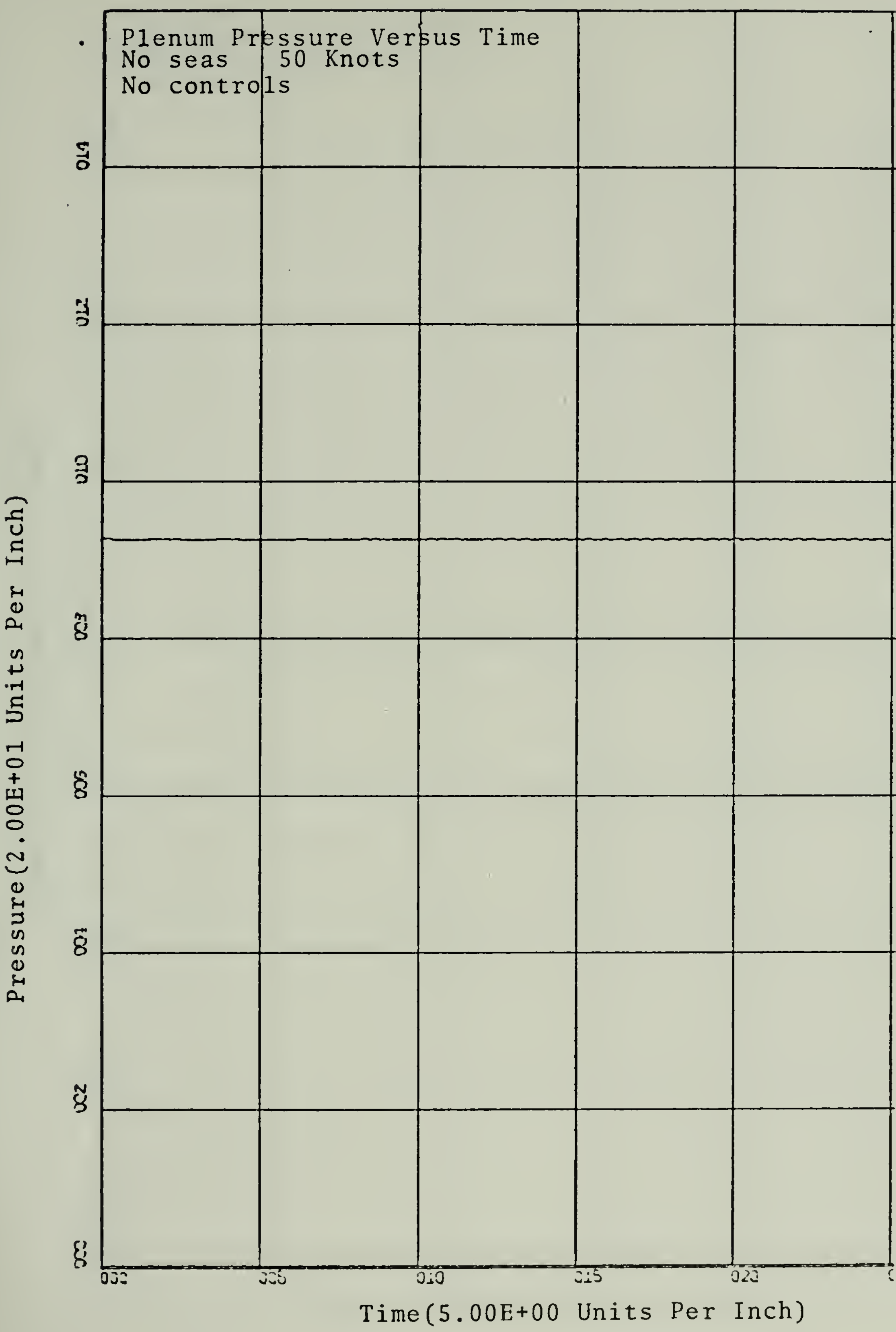

Plenum Pressure Versus Time
No seas 50 Knots
No controls
Pressure(2.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 1.

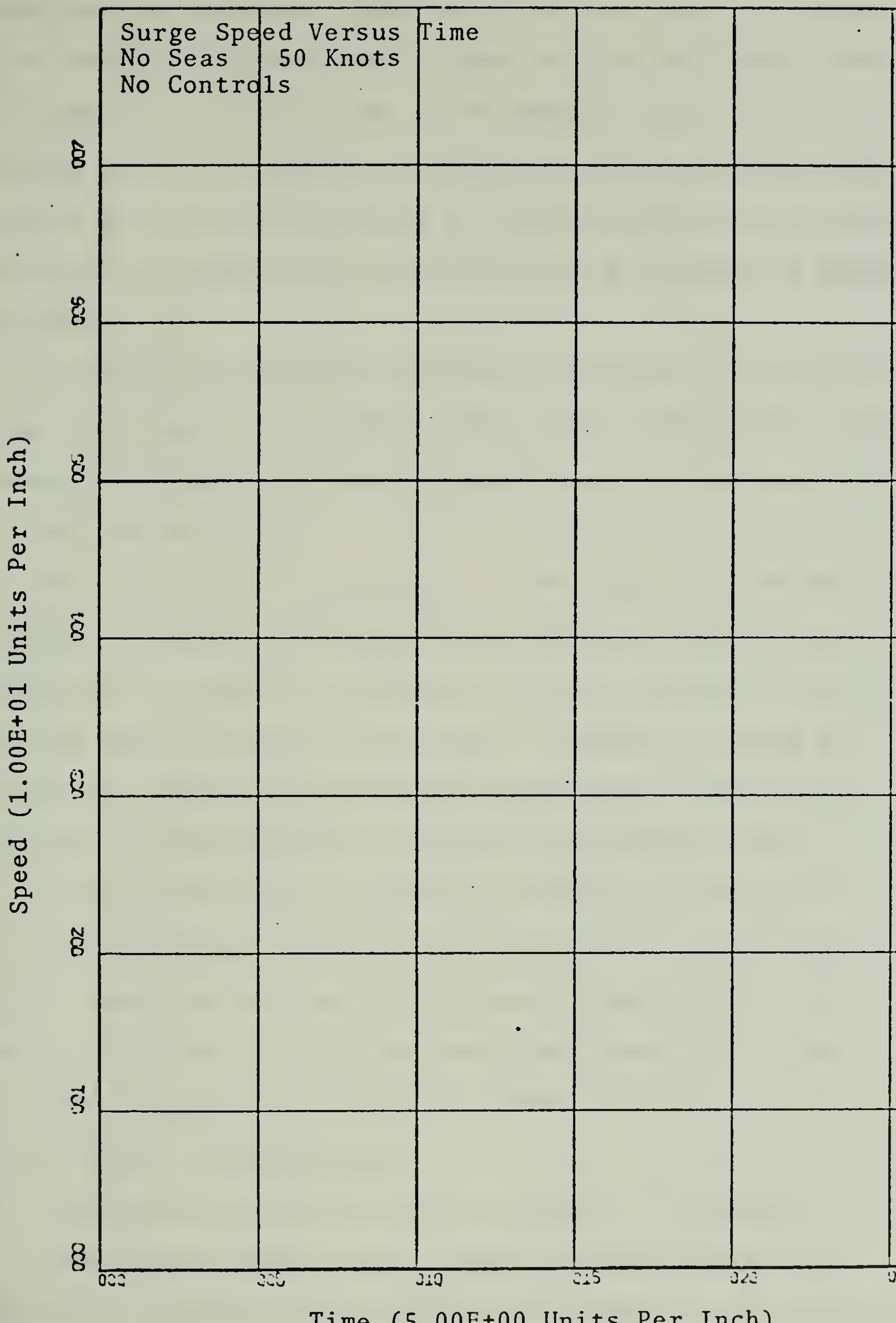

Surge Speed Versus Time
No Seas 50 Knots
No Controls
Speed (1.00E+01 Units Per Inch)
Time (5.00E+00 Units Per Inch)

Figure 2.

conditions to maintain fifty knots in calm water. Figures 3, 4, and 5 illustrate what happens to the 100-B when under the same initial conditions it encounters waves. Some venting from the sidewalls and from the stern and bow seals along with the increased drag of the waves slows the craft and draws it deeper into the water with a decrease in plenum pressure.

If the plenum pressure could be increased as the craft slows to bring it up higher in the water, reducing the drag, perhaps the craft's forward velocity could be increased to its initial velocity.

The results of a study [Ref. 2] by LCDR G. T. Forbes, a student at the Naval Postgraduate School, in which he incorporated a velocity difference signal to change the main fan rpm show that this can be done. However, a sharp increase in heave acceleration was also noted. This aggrevates an already marginal habitability parameter [Ref. 4].

Through the use of simulation studies, a heave acceleration controller is to be designed, tested, and coupled with a speed control based on plenum pressure variations only. The objective will be good speed control with no increase in heave acceleration or even a noticeable reduction in heave acceleration.

The results obtained will be assumed to correspond to or closely approximate those conditions that would exist if such a controller were physically present in the actual SES 100-B.

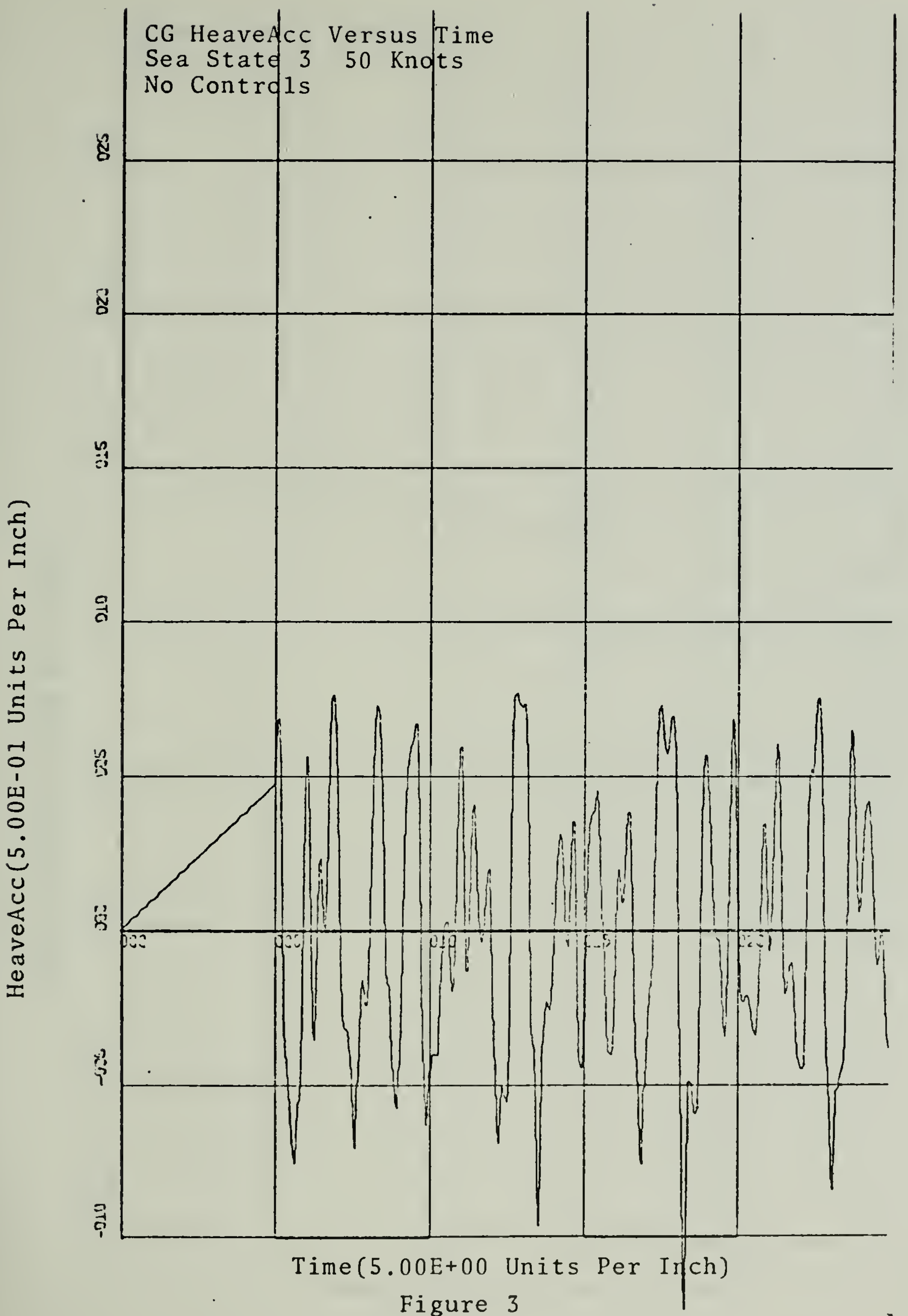
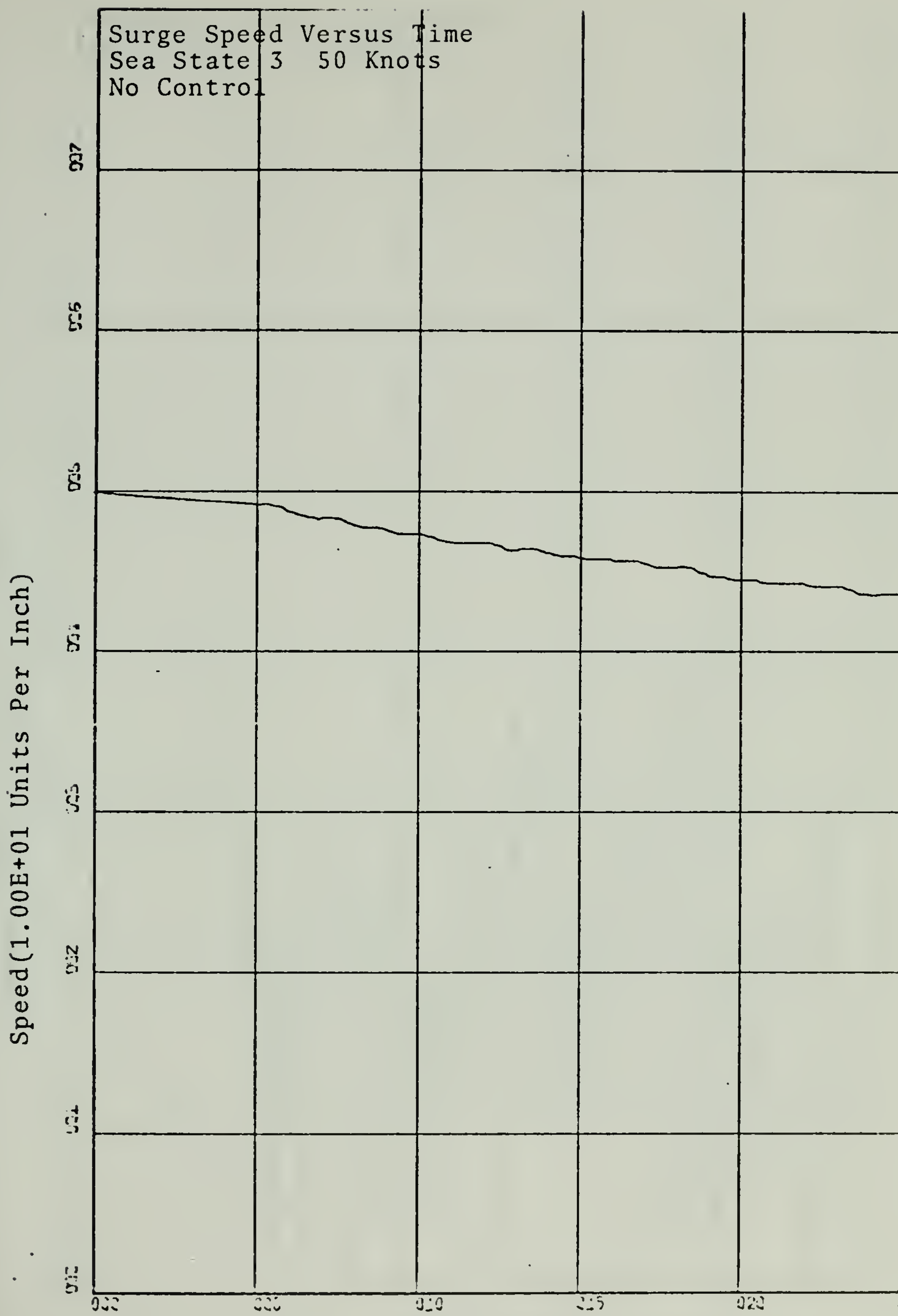
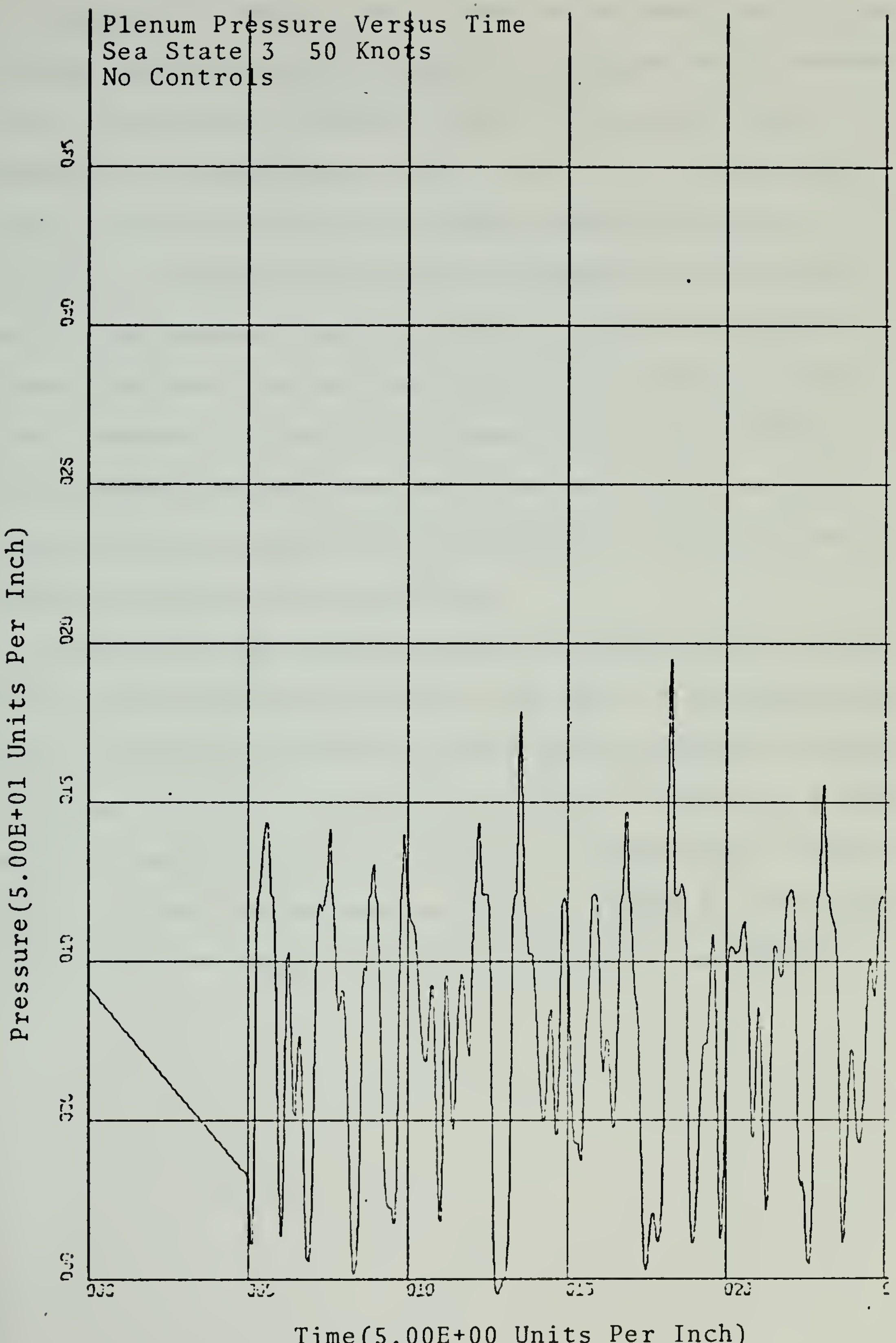

CG HeaveAcc Versus Time
Sea State 3 50 Knots
No Controls
HeaveAcc(5.00E-01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 3


Surge Speed Versus Time
Sea State 3 50 Knots
No Control
Speed(1.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)
Figure 4.


Plenum Pressure Versus Time
Sea State 3 50 Knots
No Controls
Pressure(5.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)
Figure 5.

That such a design should make use of some type of controlled venting of plenum pressure is suggested by observation of some motion pictures taken by the Naval Ship Research and Development Center [Ref. 5] of a model CAB during test runs involving certain membrane studies. As the model CAB with a non-perforated membrane encountered waves, the membrane expanded and contracted with changes in plenum pressure causing some reduction in heave acceleration. Further footage of the model utilizing a membrane with a round opening likewise illustrated this same phenomena with the magnitude of the membrane flexation determining the size of the vent hole.

Because of the increase in heave acceleration created by the simple velocity control loop [Ref. 2] is much greater in the negative direction as the plenum pressure is sharply increased, a form of controlled venting by means of a opening and closing louver system will be investigated. Provision for the replacement of the air vented by the louver system will be compensated for by main fan rpm changes.

III. PROCEDURE FOR DESIGN

A. DESIGN CONSIDERATIONS

Before the actual design of such a controller can be attempted, a basic understanding of the concepts behind the unique characteristics of the CAB is necessary. Essential to the proper operation of the craft is the maintaining of its "bubble" through a series of blowers or fans. These fans produce a pressure increase in the volume enclosed by the bow and stern seals and the rigid sidewalls. This volume of pressurized air or plenum functions to support the majority of the craft's mass by the displacement of water as in a displacement hull ship. As the craft moves forward under any of several conventional means such as water jets or supercavitating propellers, it reaches a velocity as mentioned before where it goes up "on the hump." At this point the bubble has moved aft under the stern seal, the bow has risen and wave drag coupled with the skin friction drag has been sharply reduced to well below that which is experienced by displacement vessels. This produces a thrust vs. velocity ratio at this point which shows an increase in velocity for a decrease in thrust.

Heave acceleration or acceleration in the z-direction is coupled directly to the fluctuations of plenum pressure. In calm water conditions with plenum pressure at a constant value, the craft experiences no heave acceleration, however,

when the CAB passes over a wave peak the resultant displacement by a more dense substance compresses the air and creates an upward force in the negative z-direction, conversely when the CAB passes over a wave trough a rarification occurs bringing the craft downward and compressing the plenum until it is again supported by the proper pressure.

In order to alleviate these accelerations completely, a force of equal strength in the opposite direction is necessary. Dampening of the acceleration by reduction of the original force is also possible and this is the basis for the study here.

Acceleration in the negative direction is caused by a sudden increase in plenum pressure. If this increase could be slowed so that the next wave depression would have time to reduce it again or if this sudden increase could be reduced in magnitude, the effect would be to decrease the amount of acceleration.

In order to prevent or reduce the acceleration in the positive direction when the craft drops into a depression, the plenum pressure must be brought back to the nominal value without sudden fluctuations. Venting by definition is allowing a certain amount of air to escape from the plenum, therefore, venting by itself, even controlled venting, worsens the situation but if coupled with an rpm increase to increase the plenum pressure should dampen the acceleration.

B. DESIGN OF THE HEAVE CONTROL

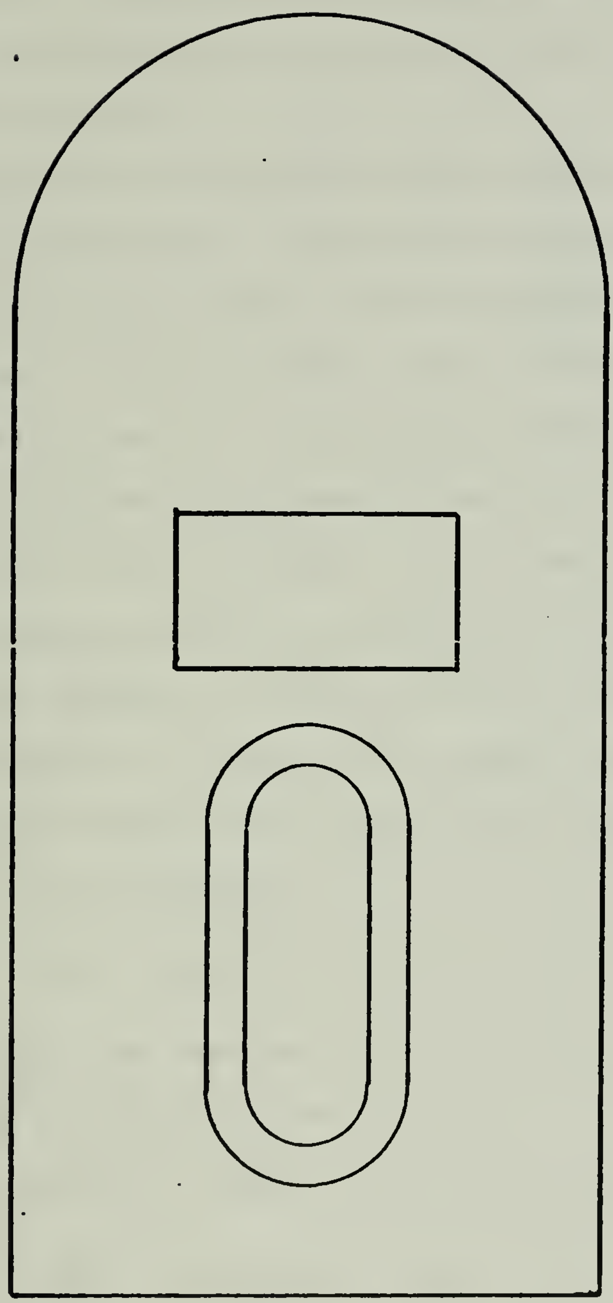
Several parameters were considered during the design of the louver system. Whether the system consisted of a single louver or a series of smaller ones, the total area vented by the louver was certainly important. For modelling purposes a single, horizontally sliding louver, which was sixteen feet by nine feet, was decided upon (see Figure 6).

Some type of signal had to be generated or obtained from an already existing source to position the louver. Two alternatives were already available from the model. The first, plenum pressure, was discussed but discarded in favor of using the heave acceleration measurements at the center of gravity. This does not preclude the use of plenum pressure measurements for future studies.

Taking two separate measurements of $\ddot{Z}$, the first, S1 was to be multiplied by a gain factor, k_1, and then summed with a more extensively modified S2 (see Figure 7).

Because of power considerations, S2 was to be constructed to act as a "steady-state" positioning signal around which S1 would fluctuate. As wave conditions were encountered producing heave accelerations, S2 would act to bring the louver to an appropriate median position with the magnitude of the accelerations determining the strength of S2.

The scheme of modification began with the initial thought that a relative measure of the magnitude of the accelerations could be obtained by passing the positive portion of the signal through a low pass filter thereby



Scale: 11':1"

Relative size of a 16' by 9' Louver on the SES 100-B.

Figure 6.

integrating it. Before this was pursued further, it was noted that there existed substantial differences in the magnitude of the positive and negative accelerations. In order to obtain a representative measure of the greater magnitude, the acceleration signal was first passed through a full-wave rectifier.

Construction of the low-pass filter (Figure 7), resulted from the use of DSL/360, a simulation-language available at the Naval Postgraduate School, Bode diagrams and studies using the model of the SES 100B. One of the objectives of the filter was to provide a fairly fast rise time as waves were encountered, but conversely it was not to decay too quickly. After initial designs with a simple low-pass filter with a single resistor and capacitor, it was decided to insert a diode (Figure 8) between the full-wave rectifier and R1. Therefore, as long as the signal voltage was rising, the diode would conduct and charge up the capacitor.

When /S1/ was increasing:

$$\dot{S}2 = (.91*/S2/ - S2) \div \tau_1$$

where τ_1 is the time constant R1*C. For the purposes of the study, τ_1 was set equal to two seconds.

However, when /S1/ begins decreasing then:

$$\dot{S}2 = ((V_{cap}*\tau_2) - S2) \div \tau_2.$$

Here V_{cap} is the voltage on the capacitor at peak signal and τ_2 is the time constant R2*C. Since R2 was chosen to be ten times R1, τ_2 became twenty seconds reducing the ripple considerably.

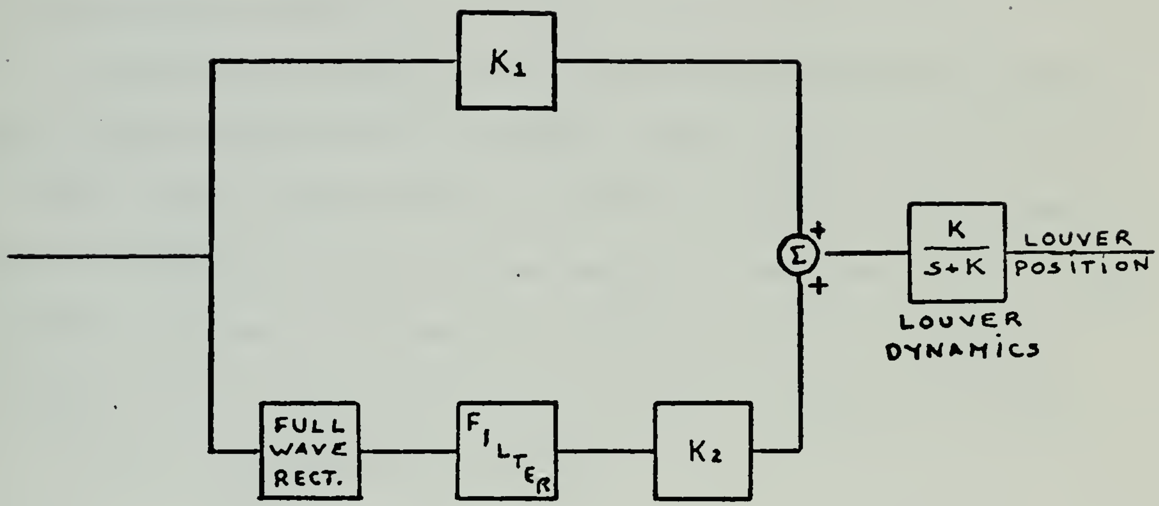


Figure 7. Block Diagram of Heave Control.

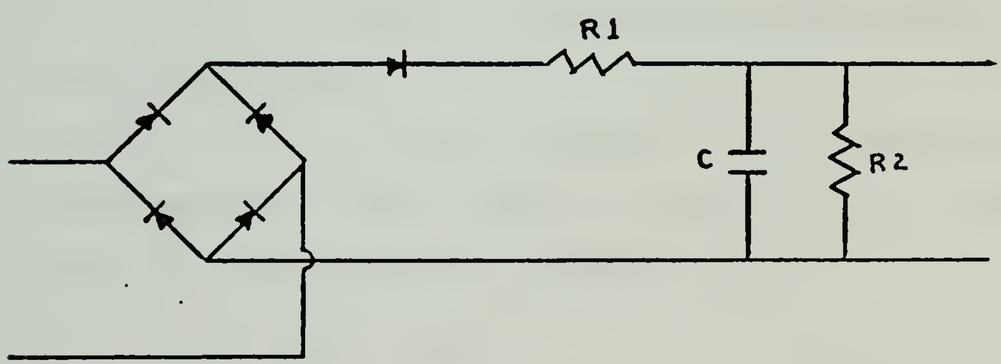


Figure 8. Rectifier and Filter.

The investigations by DSL/360 and the Bode Diagrams indicate that a certain amount on signal attenuation was present and was dependent of wave frequency.

The values to be used for the gains k_1 and k_2 were to be determined next.

Beginning with k_2, it was envisioned that the signal, S2, when multiplied by the gain factor, k_2, would provide a half open "steady-state" position when the craft experienced sustained positive and negative two gee accelerations with the signal S1 times the gain factor, k_1, providing fully open or closed louver position at the peak values.

Initial runs were made with:

$$S = -.25S1 + .25S2.$$

These runs were with simple sinusoidal frequencies and produced heave accelerations of only about .2 to .8 gees. Moreover, the attenuation of S2 was quite significant; in some cases about 50 percent, reducing the effectiveness of the louver positioning.

The gain factor, k_2, was increased to 1.0 and the same runs were repeated. This time the results were more favorable and the investigations continued with

$$S = -.25S1 + 1.0S2.$$

Note that k_1 is negative in sign, resulting in a louver system that is less open during positive accelerations as it should be.

It has occurred to the author and will perhaps to the reader that single optimal values for k_1 and k_2 probably

do not exist. Because of the systems dependency on wave frequency and intensity, some type of self-adaptive gain function may be necessary. It is certainly true that differences in the pressure within the plenum cause different masses of air to be vented from equivalent areas. Because of time limitations, the author was not able to pursue these thoughts further. The values chosen for k_1 and k_2 were considered sufficient for the immediate objectives.

Once the signal, S, had been constructed, it was utilized as the input for the louver system, giving the actual louver position, S', where

$$\dot{S}' = K(S-S')$$

with K set equal to twenty.

With the heave controller functioning, attention was turned to design of the velocity control.

C. IMPLEMENTATION OF THE SPEED CONTROL

It became quickly apparent that operation of the heave controller by itself while markedly reducing the heave acceleration had a distinct disadvantage. Added to the drag of the waves and the occasional venting along the sidewalls was the loss of air mass through the louvers. With the main fans set at a nominal rpm of 1700, the craft dropped even lower into the water and speed fell sharply off.

While developing the heave controller, an interim speed control was utilized similar to that documented by Forbes [Ref. 2] in his earlier study.

In that speed control, without the heave controller, a gain, k_3, of 400 rpm per knot difference had produced satisfactory results, but with the aforementioned sharp increases in heave acceleration. Using this simple loop in conjunction with the heave controller, steady-state surge speeds were about ten to fifteen percent below the initial values. Increasing the gain brought the speed closer to the initial value but also increased the heave acceleration. It was felt that a continued increase of the gain in this loop did not present the flexibility desired.

With this in mind, better control was sought by using two control loops, compensating for the louver venting as a coarse adjustment then fine tuning with the velocity difference loop as shown in Figure 9.

Temporarily disconnecting the velocity difference loop, the fan rpm was allowed to vary and compensate for set louver positions. The curve was fairly linear in the lower region. From this graph a gain of 1100 rpm for a venting area of about 14.5 square feet or approximately 75 rpm per square foot of venting area for k_4 was taken as a starting point.

Subsequent runs with the velocity difference loop reconnected resulted in steady-state velocity values higher than the initial value. Rather than drastically increase the velocity difference loop gain which also increased heave acceleration, k_4 was reduced to 50 and k_3 was increased slightly to 500.

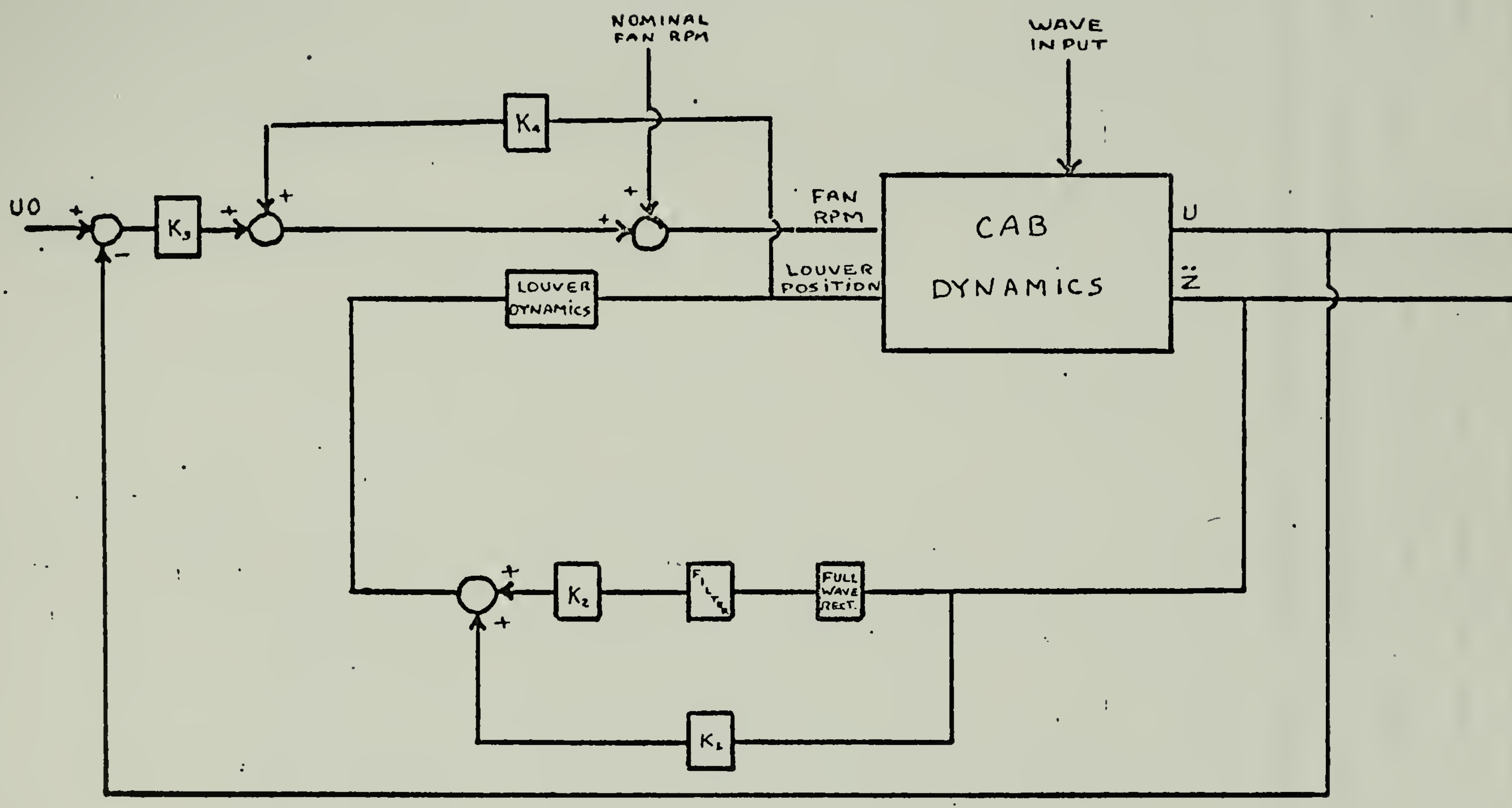


Figure 9. Block Diagram of the Heave/Velocity Controller.

The design of both the heave controller and velocity loops required a great deal of computer time and many separate runs. Up to this point basic theory has been discussed and explanations as to the course of the investigations have been innumerated. Representative data from this progression has been compiled and is annotated in the next few pages.

IV. SIMULATION INVESTIGATIONS

A. SINGLE FREQUENCY SINUSOIDAL WAVES

Because of the large amount of computer time required for even a few seconds of simulation time, certain limitations had to be adhered to in order to complete these studies. It was decided to restrict the wave frequencies for the development phase of the investigation to three. These were chosen from the eight frequencies from which Sea State 3 is artifically produced for sea state runs. The lowest frequency, 0.766222 radians per sec, the highest, 2.577250 radians per sec and middle frequency 1.532442 radians per sec were picked. All runs during the development stages were at fifty knots with wave amplitude of one foot and were for a duration of twenty-five seconds.

Even with these limitations, a great many more runs than will be included here were made. Many of these were pertinent to the data collected here such as determination of the louver area and the gains.

From all the different computer runs the author has collected the final data from each step in the investigation and design of the controller and it will be presented in the following order in terms of the control or controls being applied at the time of the data run:

1) No controls for comparison studies,
2) Velocity difference loop only,
3) Heave control,

4) Heave control with velocity difference loop,

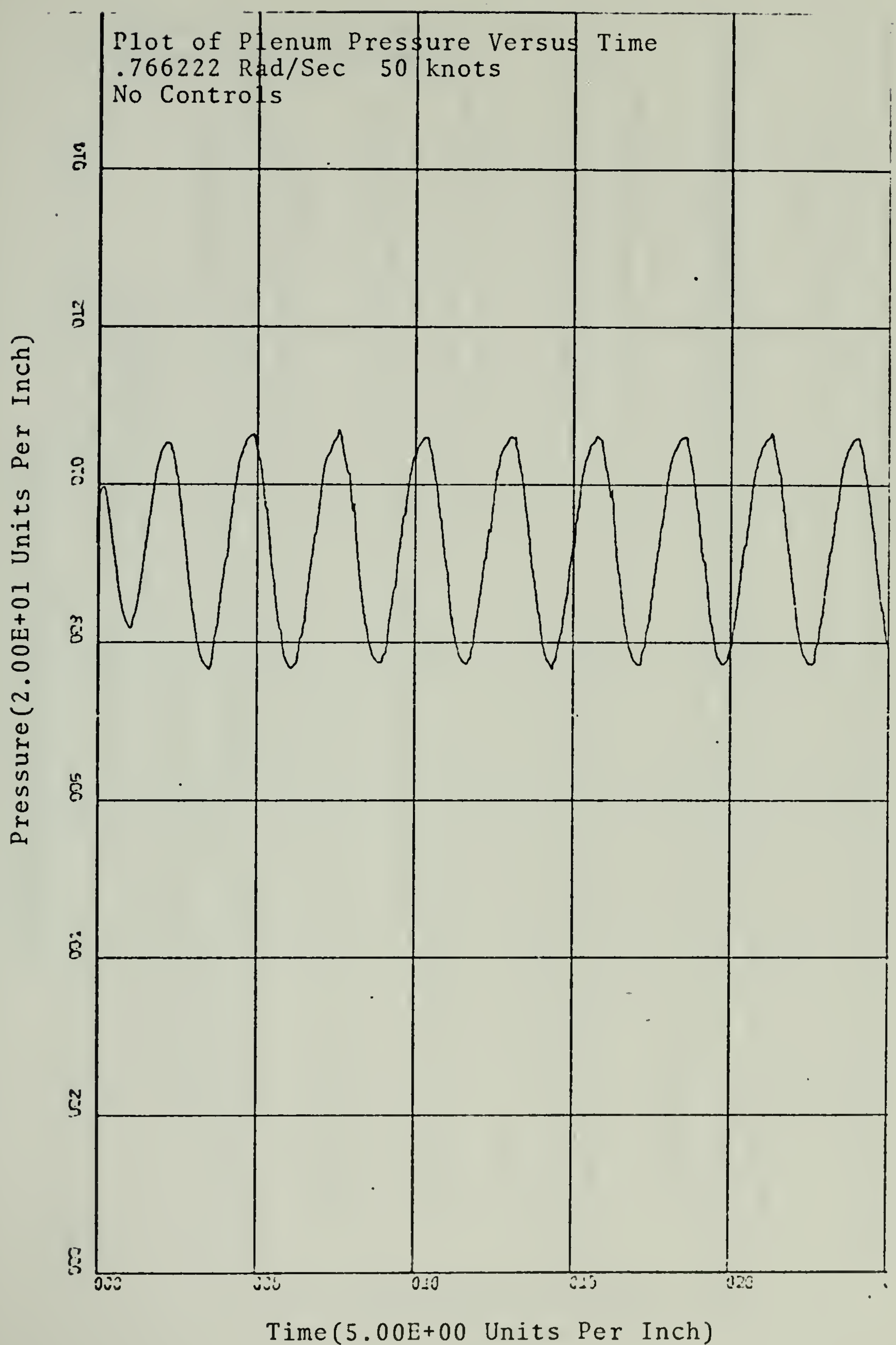
5) Heave control with final velocity control loop.

1. <u>No Control for Comparison Studies</u>

Figures 10 through 18 are plots taken from runs in which no speed or heave control was implemented. Initial conditions of draft, plenum pressure, and thrust were placed upon the craft which would cause it to maintain a forward velocity of fifty knots in calm water conditions. With the introduction of wave conditions and holding the thrust constant, it can be noted that heave accelerations build up and the forward velocity begins to fall off and after the twenty-five seconds of simulation time, steady-state conditions do not exist. Plenum pressure is plotted in lbs per square foot, center of gravity heave acceleration in gees and surge speed in knots.

2. <u>Velocity Difference Loop Only</u>

The velocity difference loop only graphs are shown in Figures 19 through 30. As can be seen by Figures 21, 25, and 29, the velocity difference loop using a gain of 400 rpm works quite well with single frequency sinusoidal waves with varying degrees of heave acceleration amplification. This amplification is highest for 1.532443 rad/sec and shows an increase of about thirty-three percent compared with less than ten percent for 0.766222 rad/sec and 2.577250 rad/sec. In all three cases, the surge speed is maintained very close to the initial conditions. Changes in the main fan rpm can be seen to closely follow the change in heave



Plot of Plenum Pressure Versus Time
.766222 Rad/Sec 50 knots
No Controls
Pressure(2.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 10.

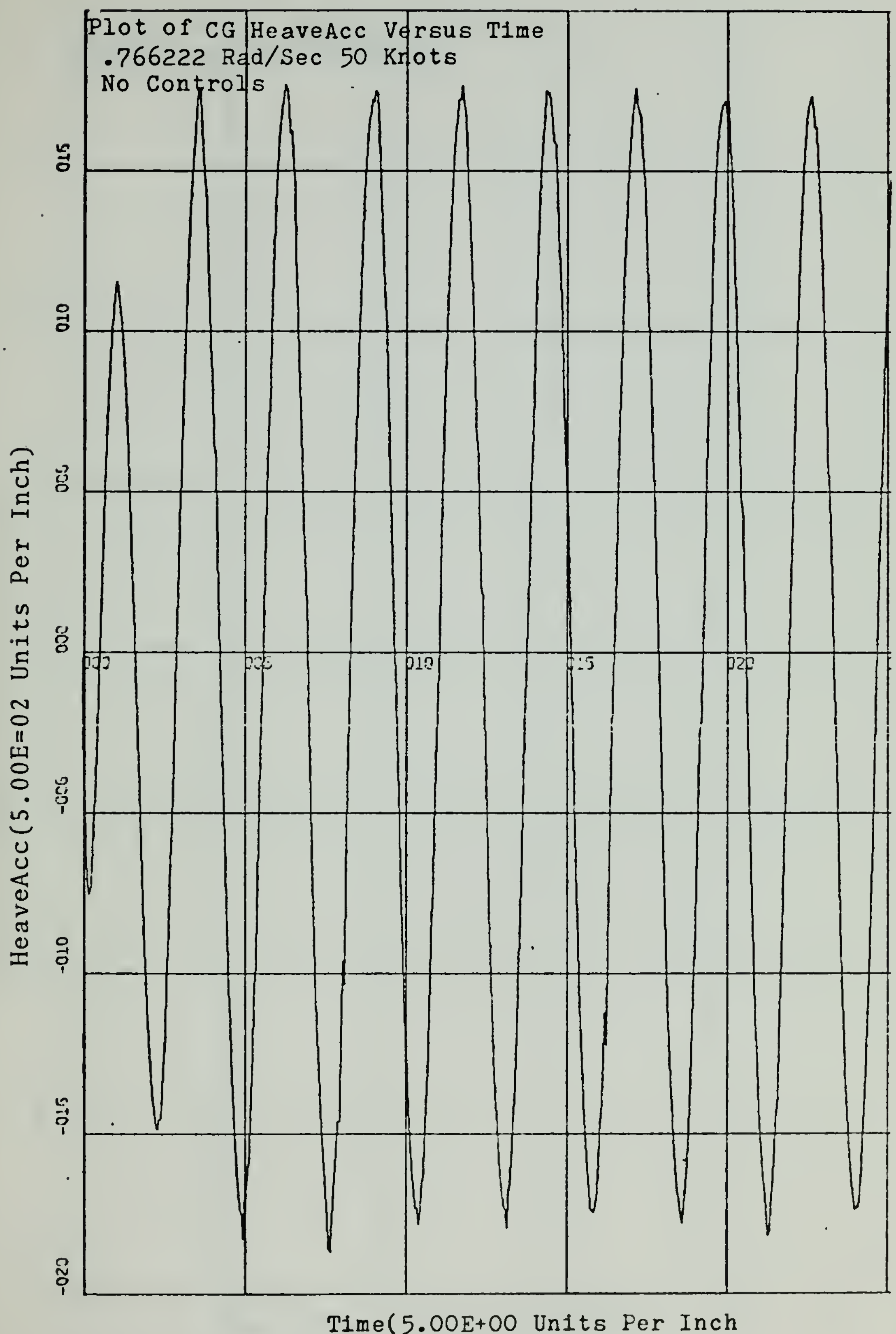
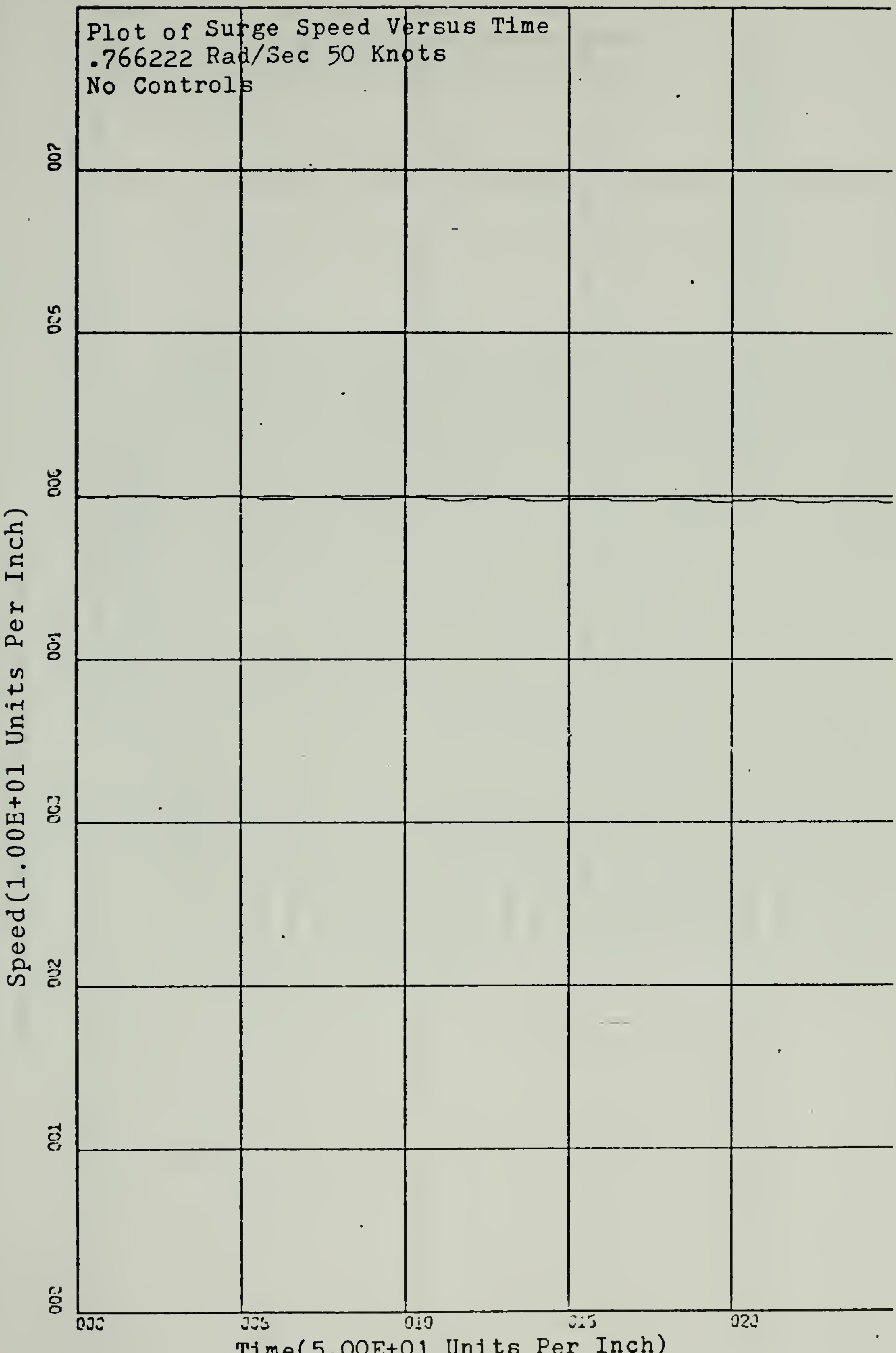

Plot of CG HeaveAcc Versus Time
.766222 Rad/Sec 50 Knots
No Controls
HeaveAcc(5.00E=02 Units Per Inch)
Time(5.00E+00 Units Per Inch

Figure 11


Plot of Surge Speed Versus Time
.766222 Rad/Sec 50 Knots
No Controls
Speed(1.00E+01 Units Per Inch)
Time(5.00E+01 Units Per Inch)
Figure 12

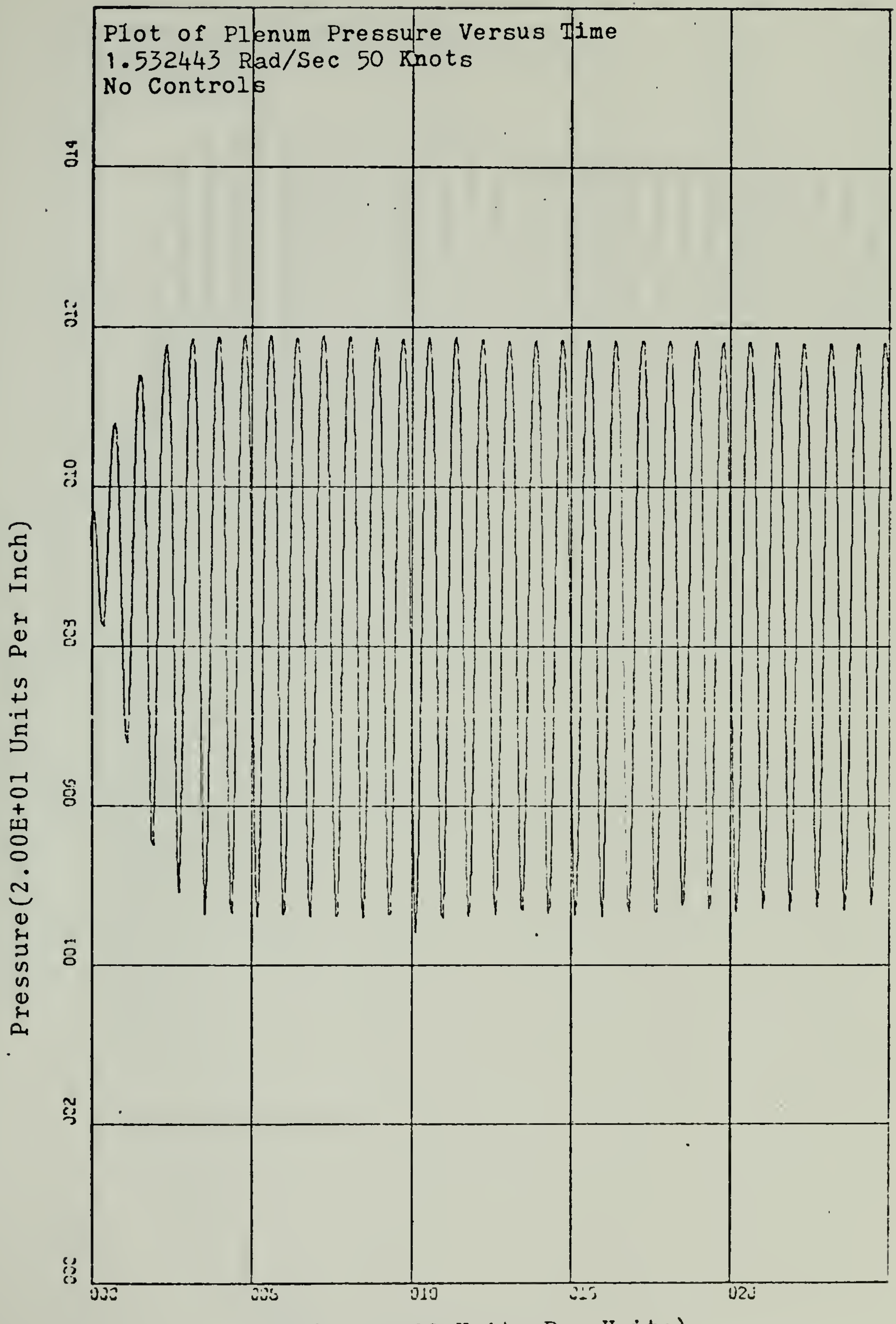

Plot of Plenum Pressure Versus Time
1.532443 Rad/Sec 50 Knots
No Controls
Pressure(2.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Units)

Figure 13

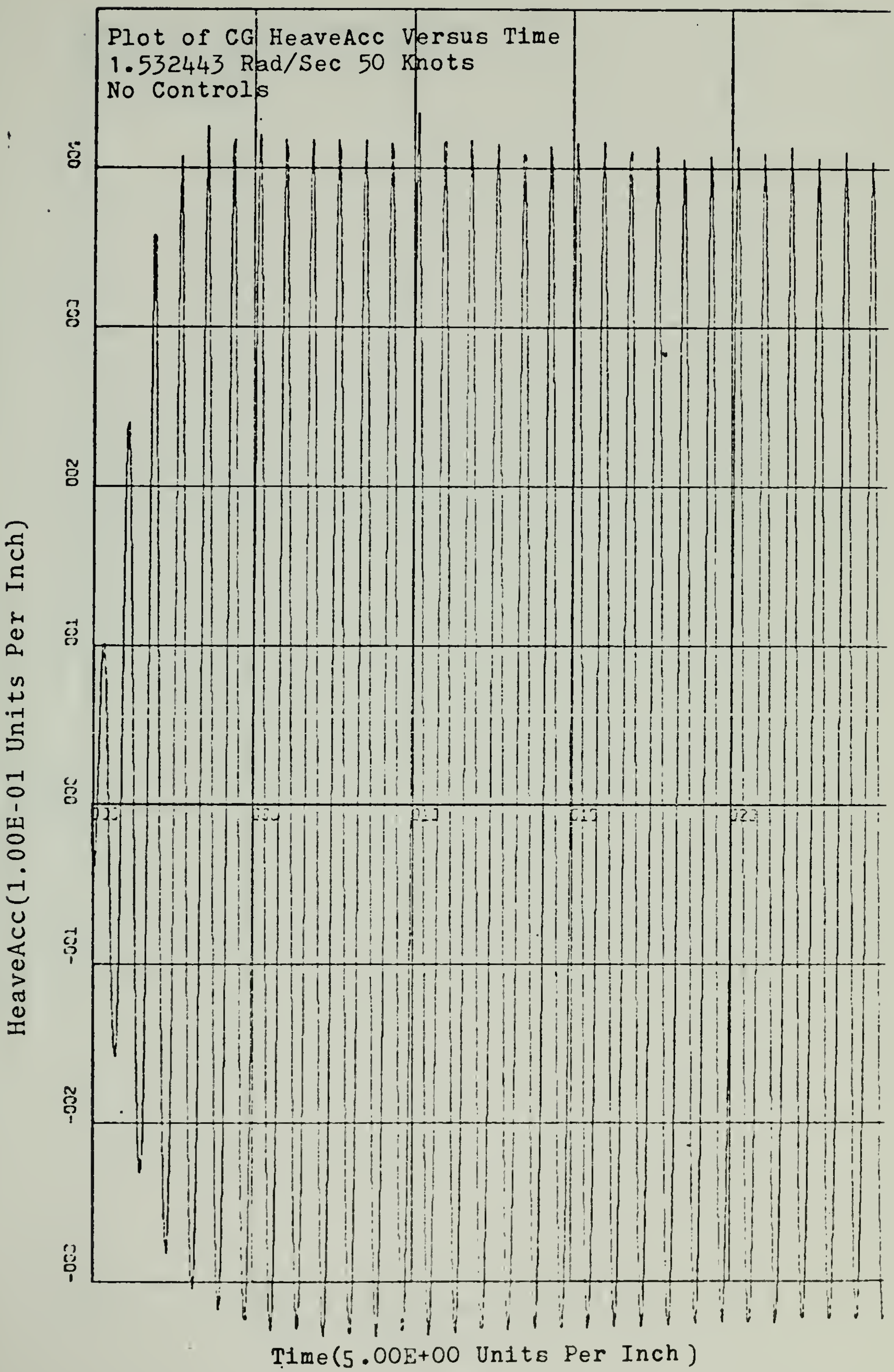
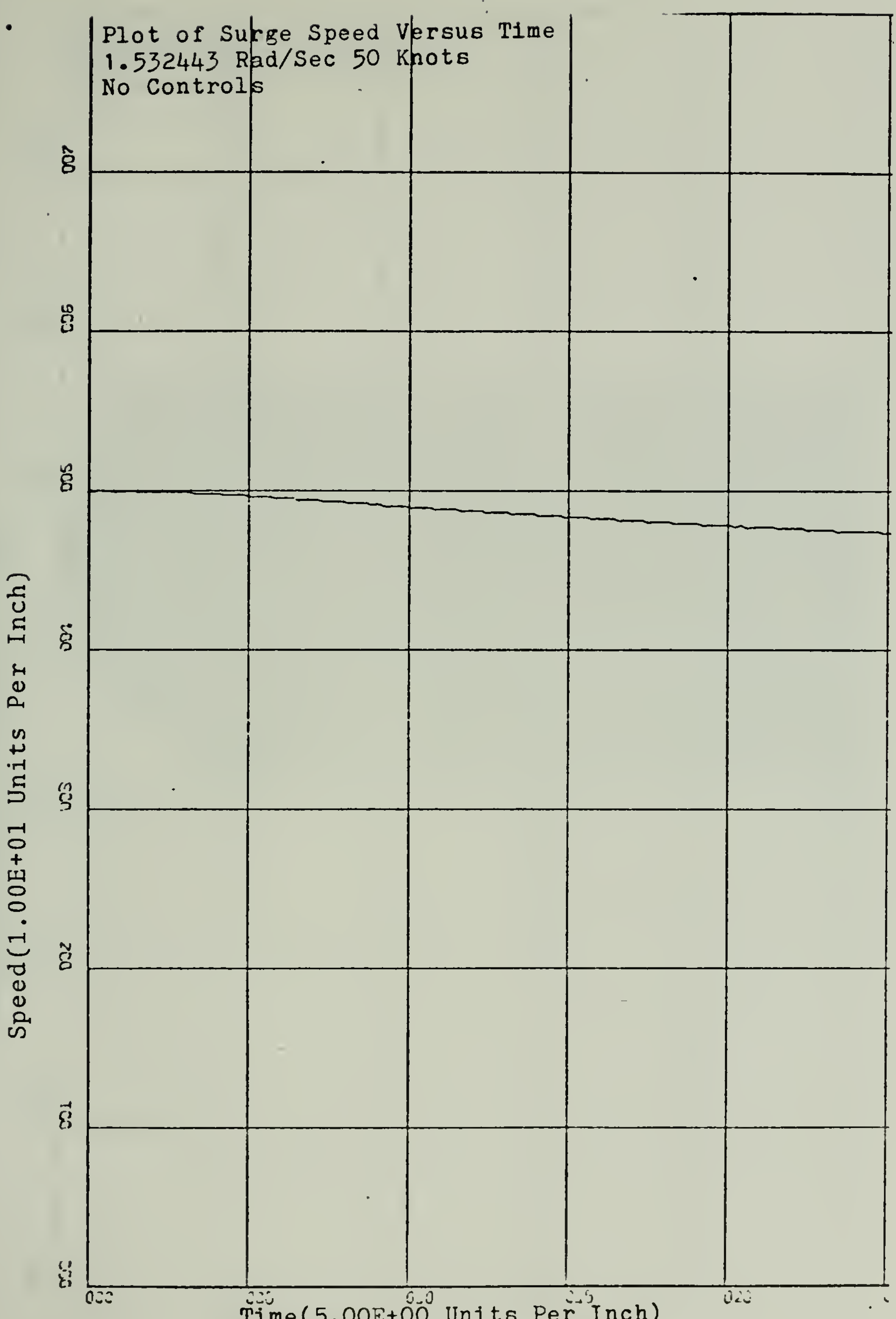

Plot of CG HeaveAcc Versus Time
1.532443 Rad/Sec 50 Knots
No Controls
HeaveAcc(1.00E-01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 14



Plot of Surge Speed Versus Time
1.532443 Rad/Sec 50 Knots
No Controls
Speed(1.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 15

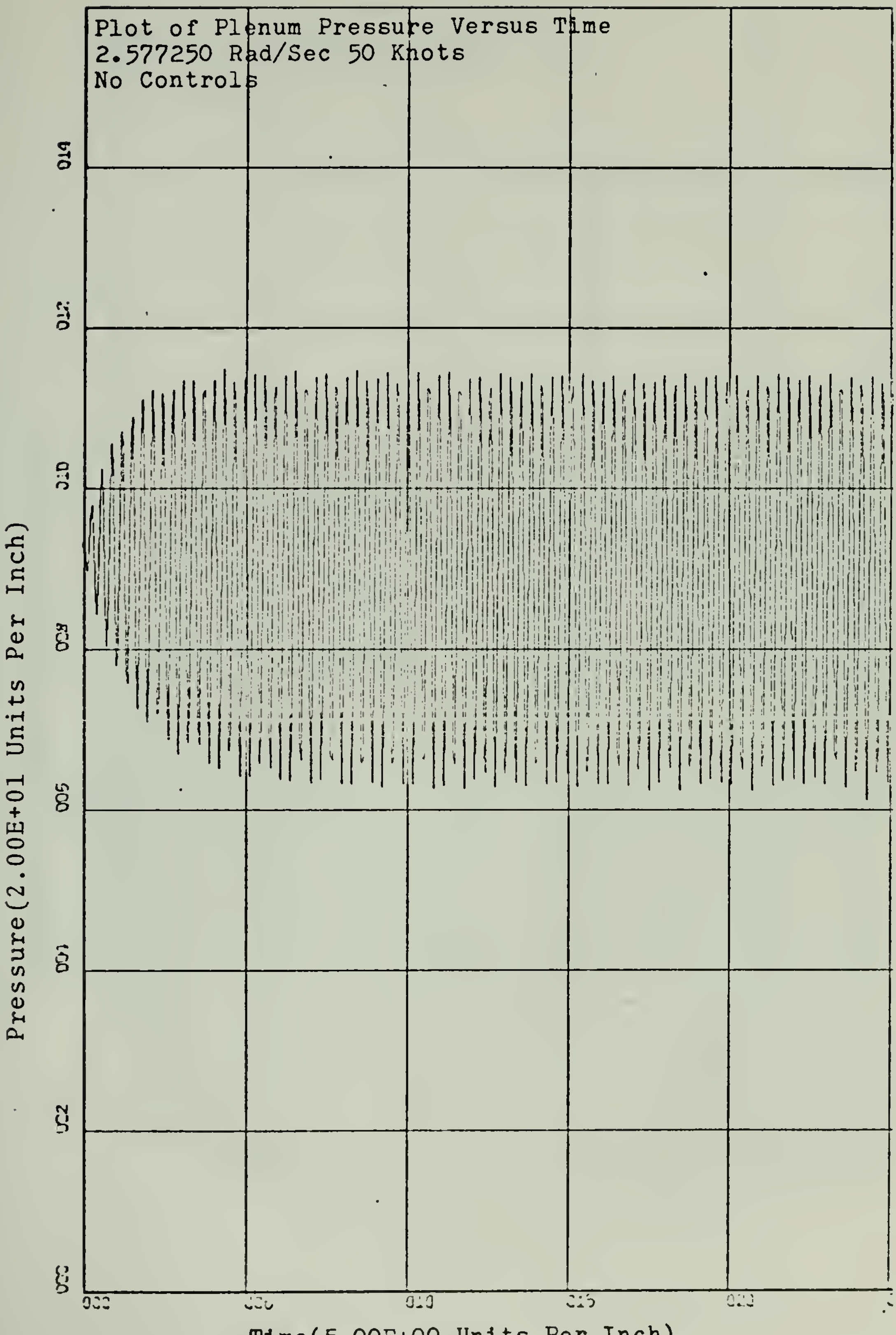
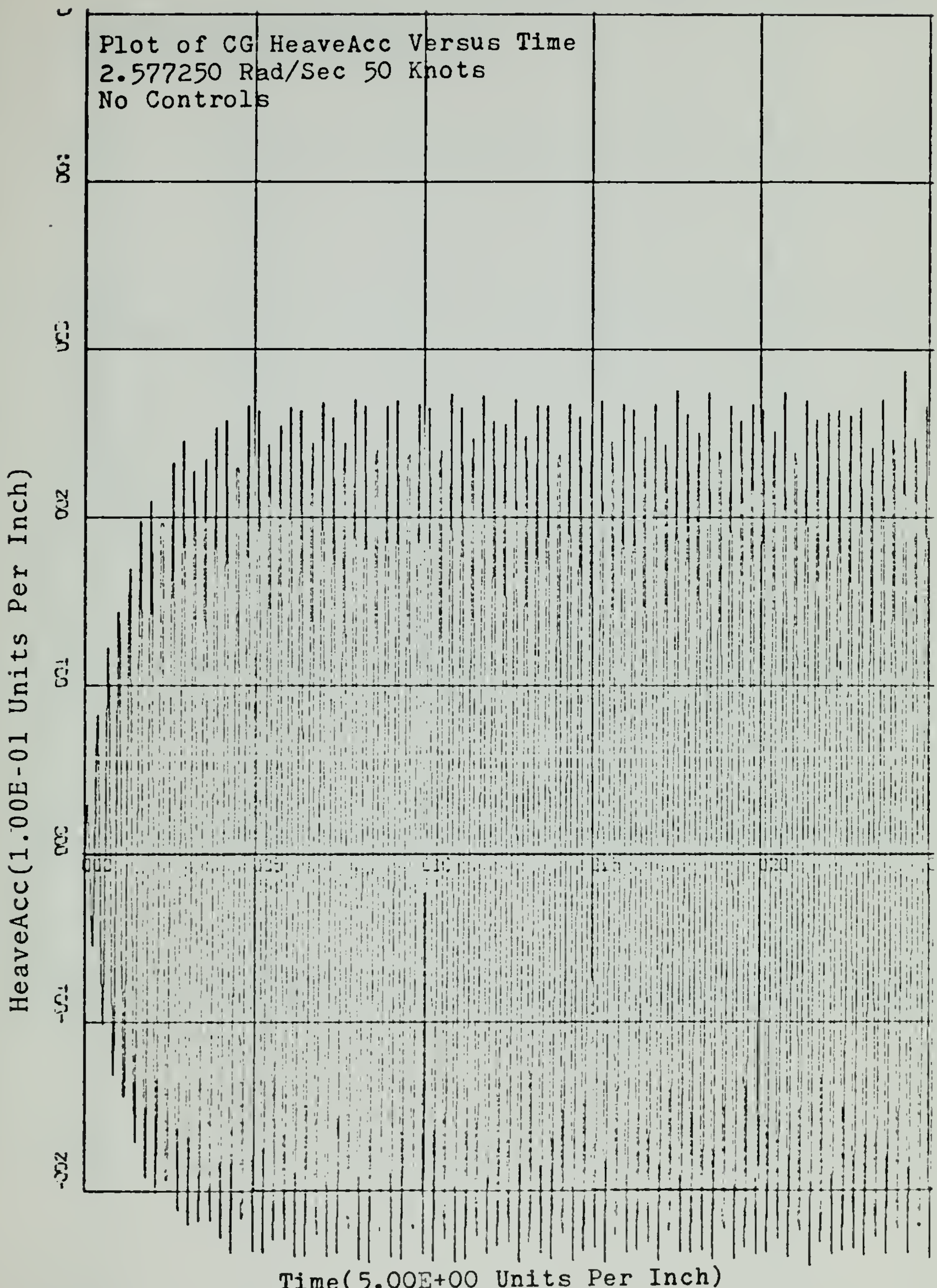

Plot of Plenum Pressure Versus Time
2.577250 Rad/Sec 50 Knots
No Controls
Pressure(2.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 16


Plot of CG HeaveAcc Versus Time
2.577250 Rad/Sec 50 Knots
No Controls
HeaveAcc(1.00E-01 Units Per Inch)
Time(5.00E+00 Units Per Inch)
Figure 17

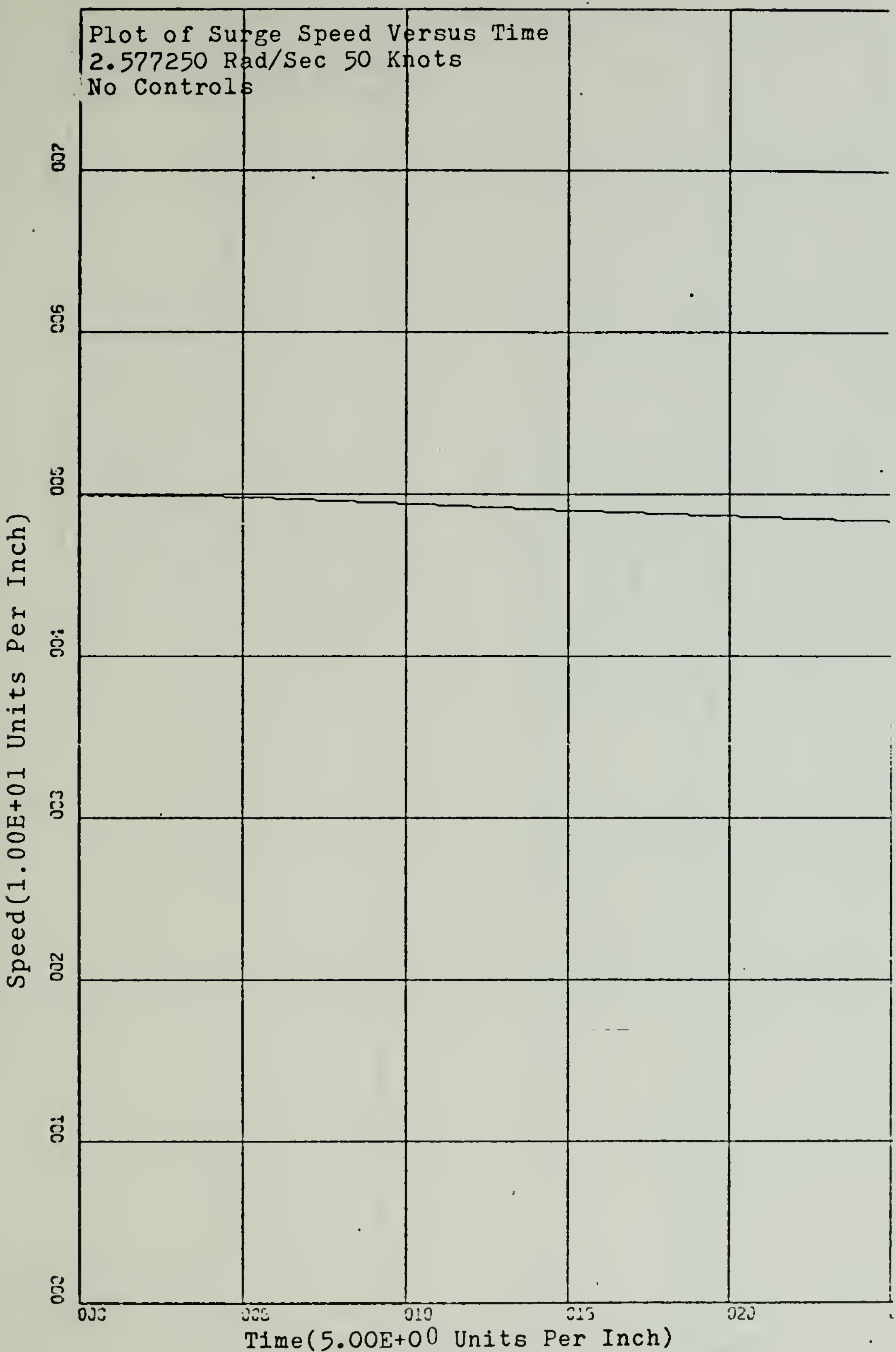

Plot of Surge Speed Versus Time
2.577250 Rad/Sec 50 Knots
No Controls
Speed(1.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 18

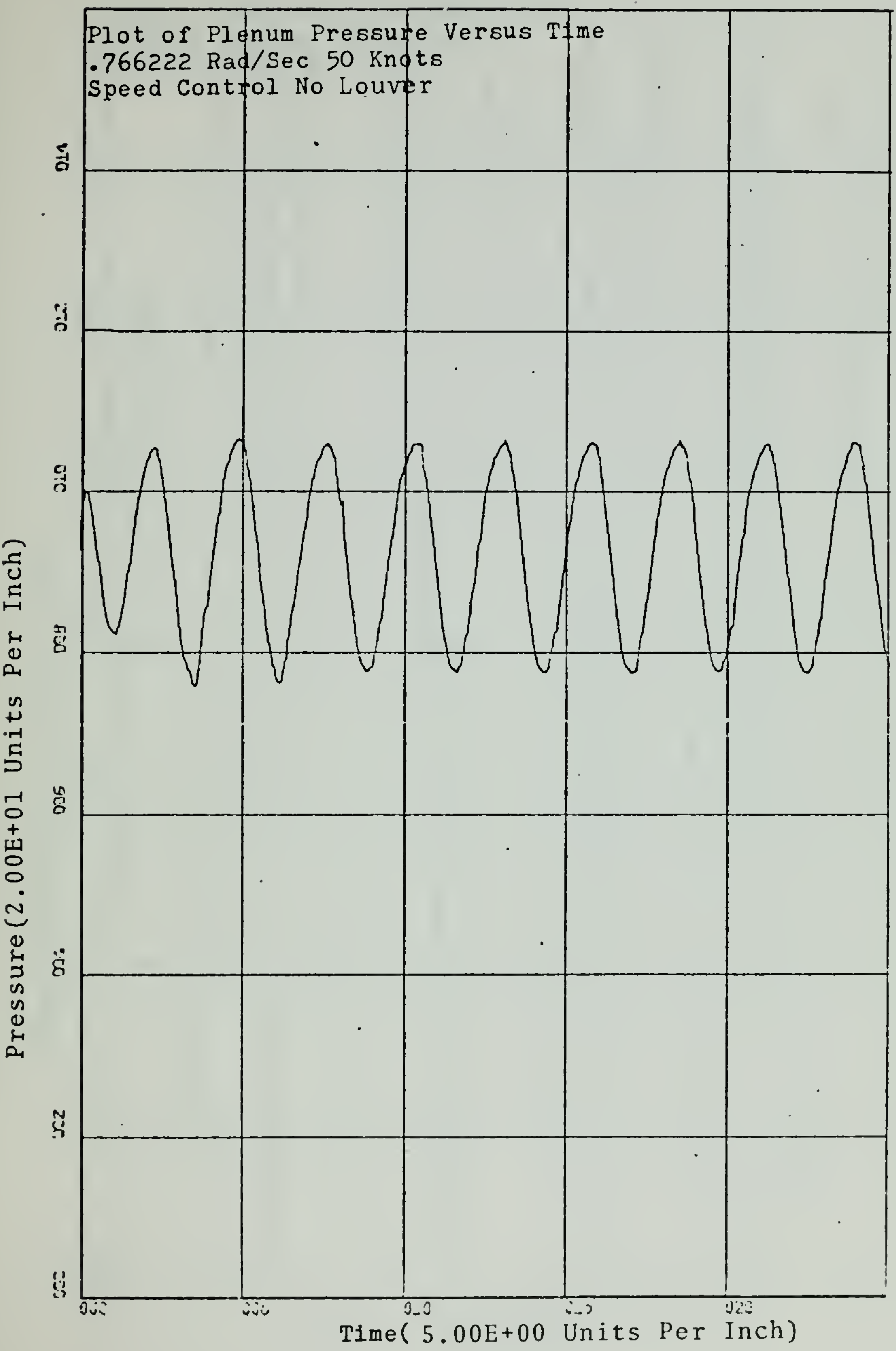

Plot of Plenum Pressure Versus Time
.766222 Rad/Sec 50 Knots
Speed Control No Louver
Pressure(2.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 19

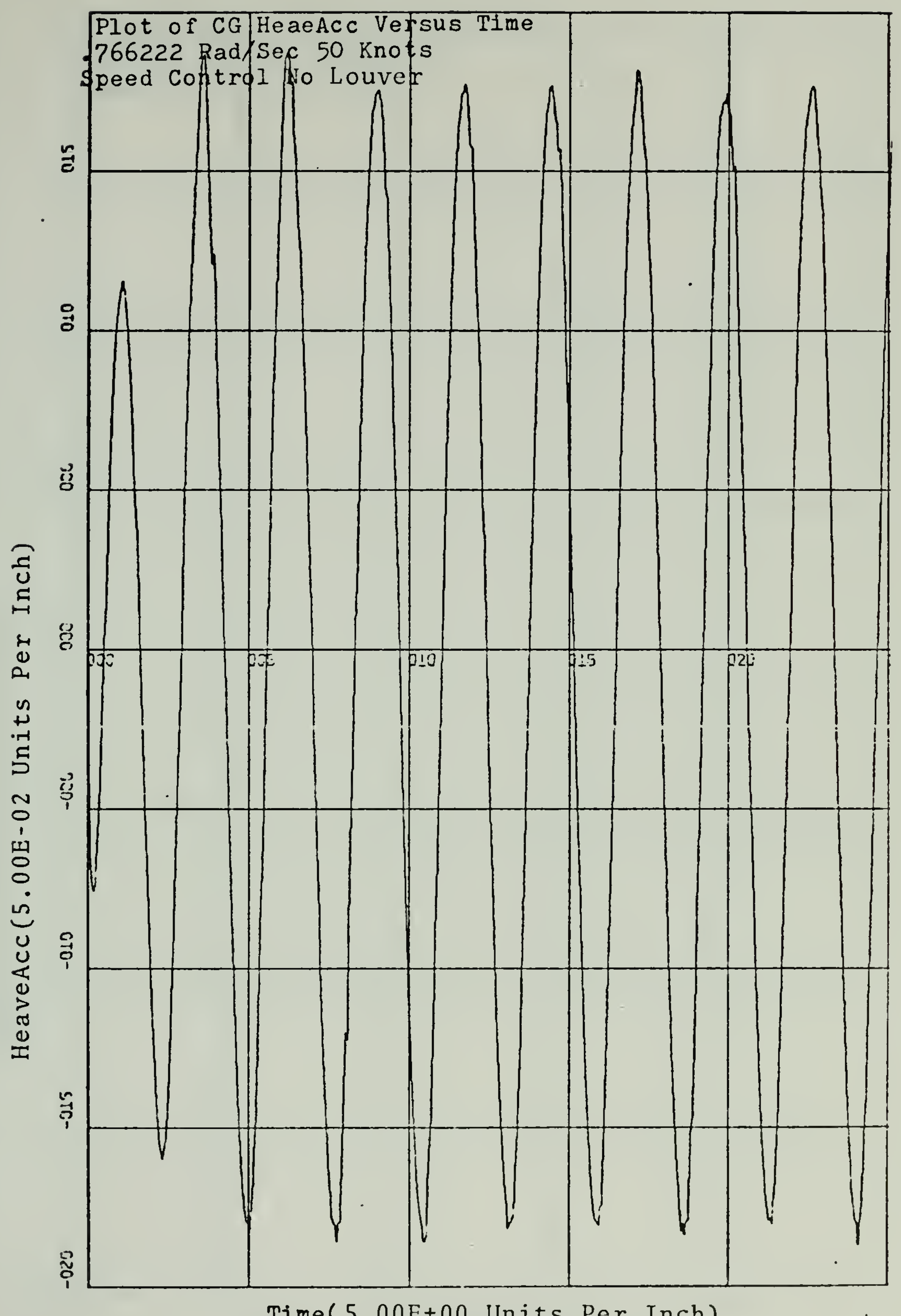

Plot of CG HeaeAcc Versus Time
.766222 Rad/Sec 50 Knots
Speed Control No Louver
HeaveAcc(5.00E-02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 20

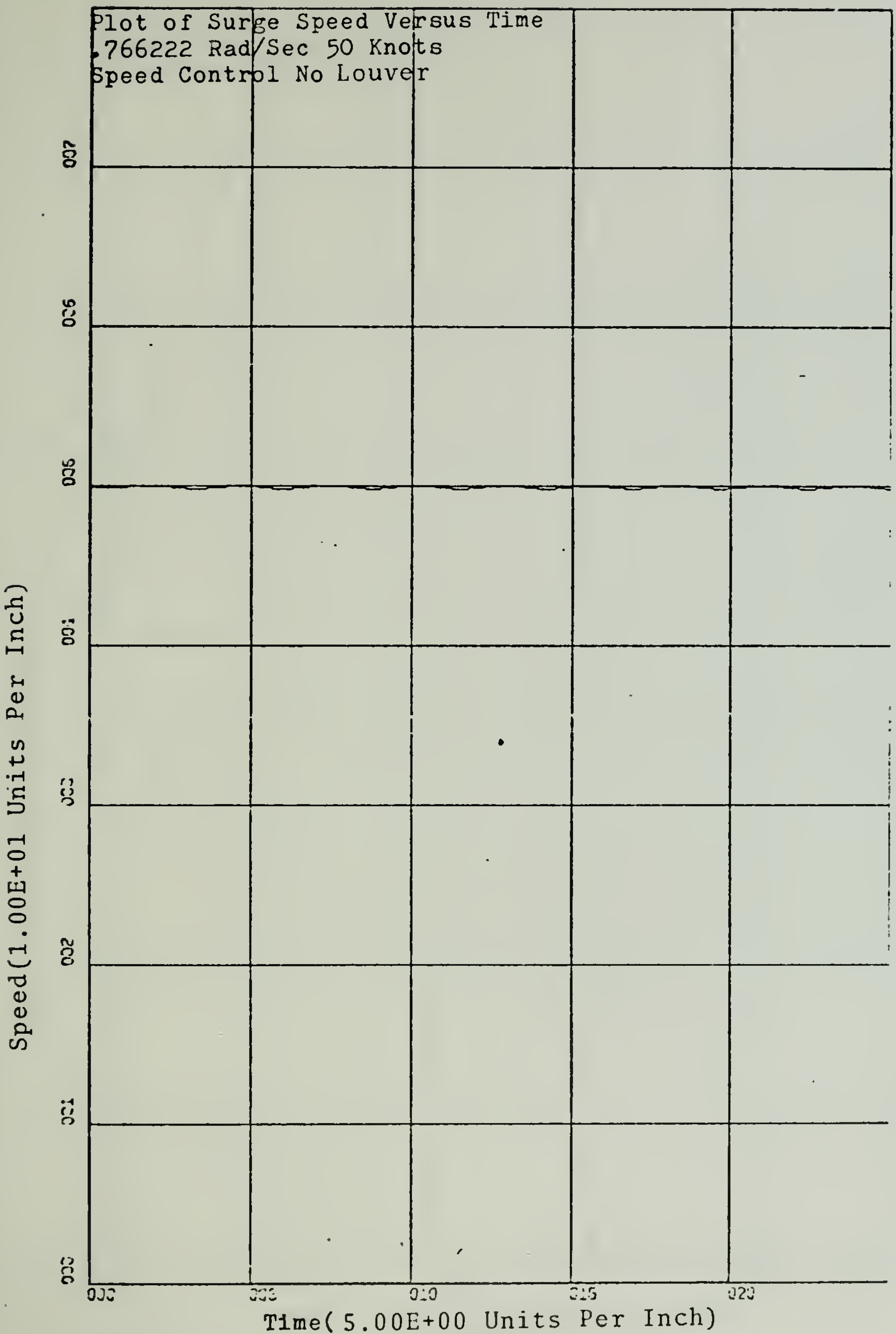

Plot of Surge Speed Versus Time
.766222 Rad/Sec 50 Knots
Speed Control No Louver
Speed(1.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 21

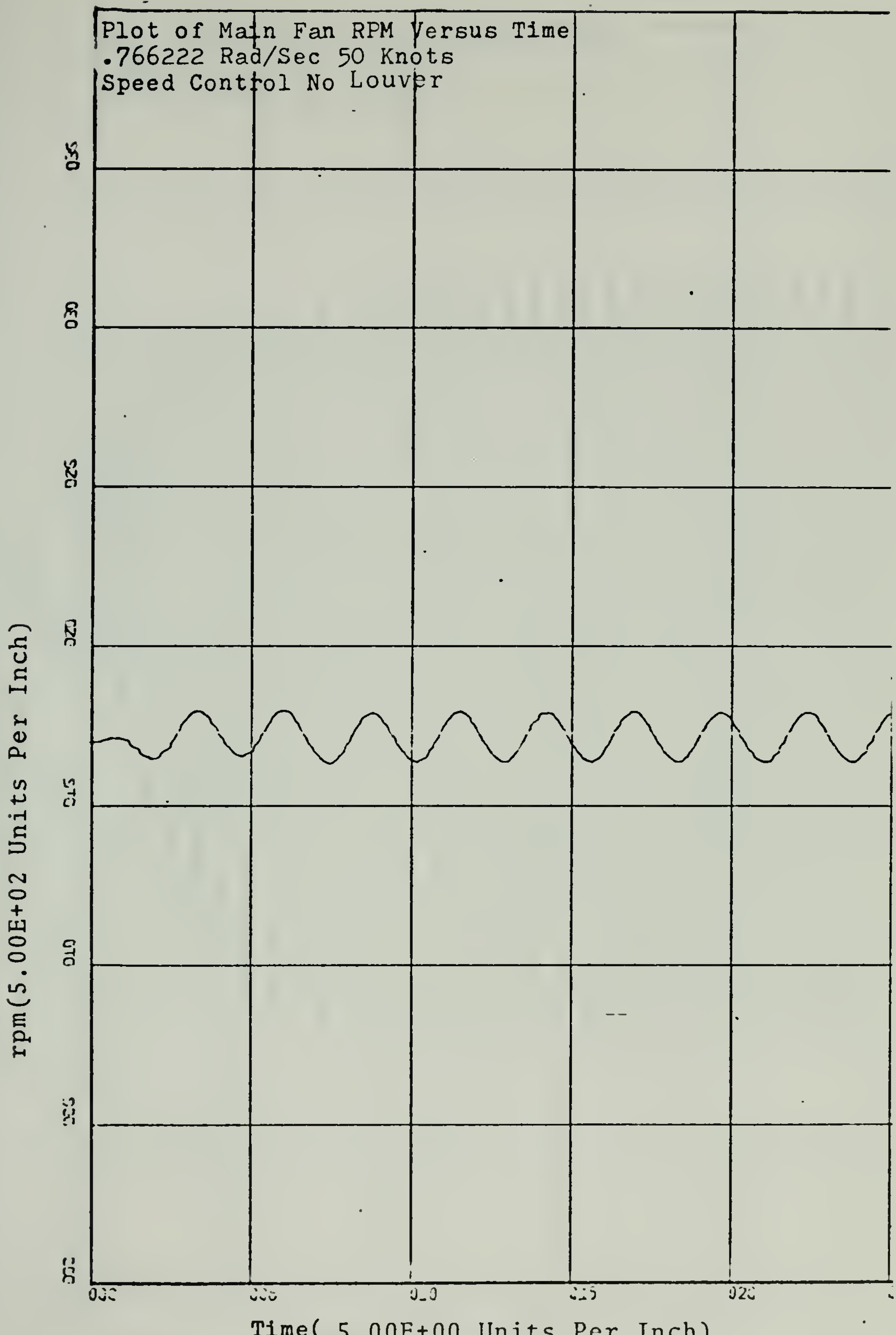
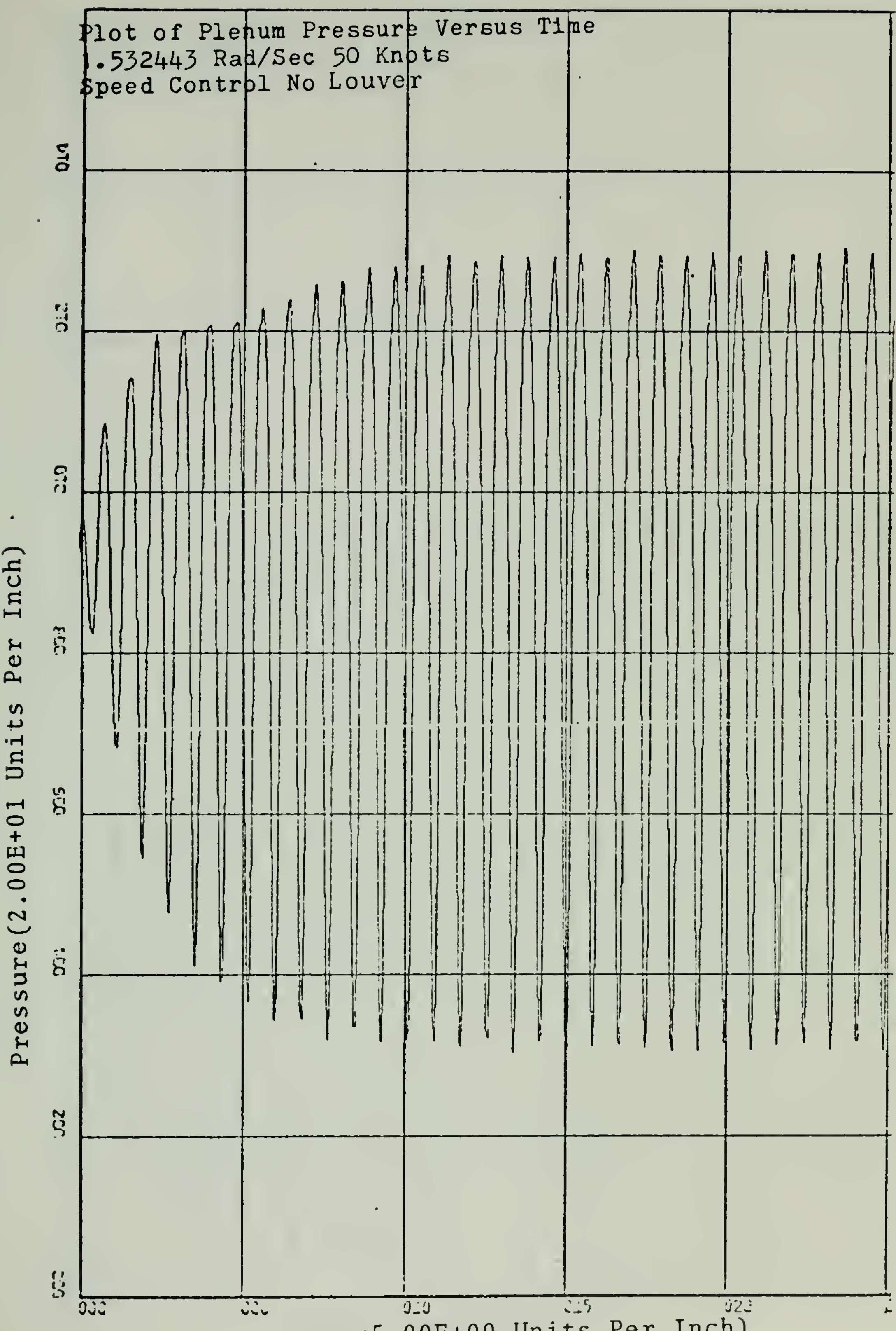

Plot of Main Fan RPM Versus Time
.766222 Rad/Sec 50 Knots
Speed Control No Louver
rpm(5.00E+02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 22



Plot of Plenum Pressure Versus Time
.532443 Rad/Sec 50 Knots
Speed Control No Louver
Pressure(2.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 23

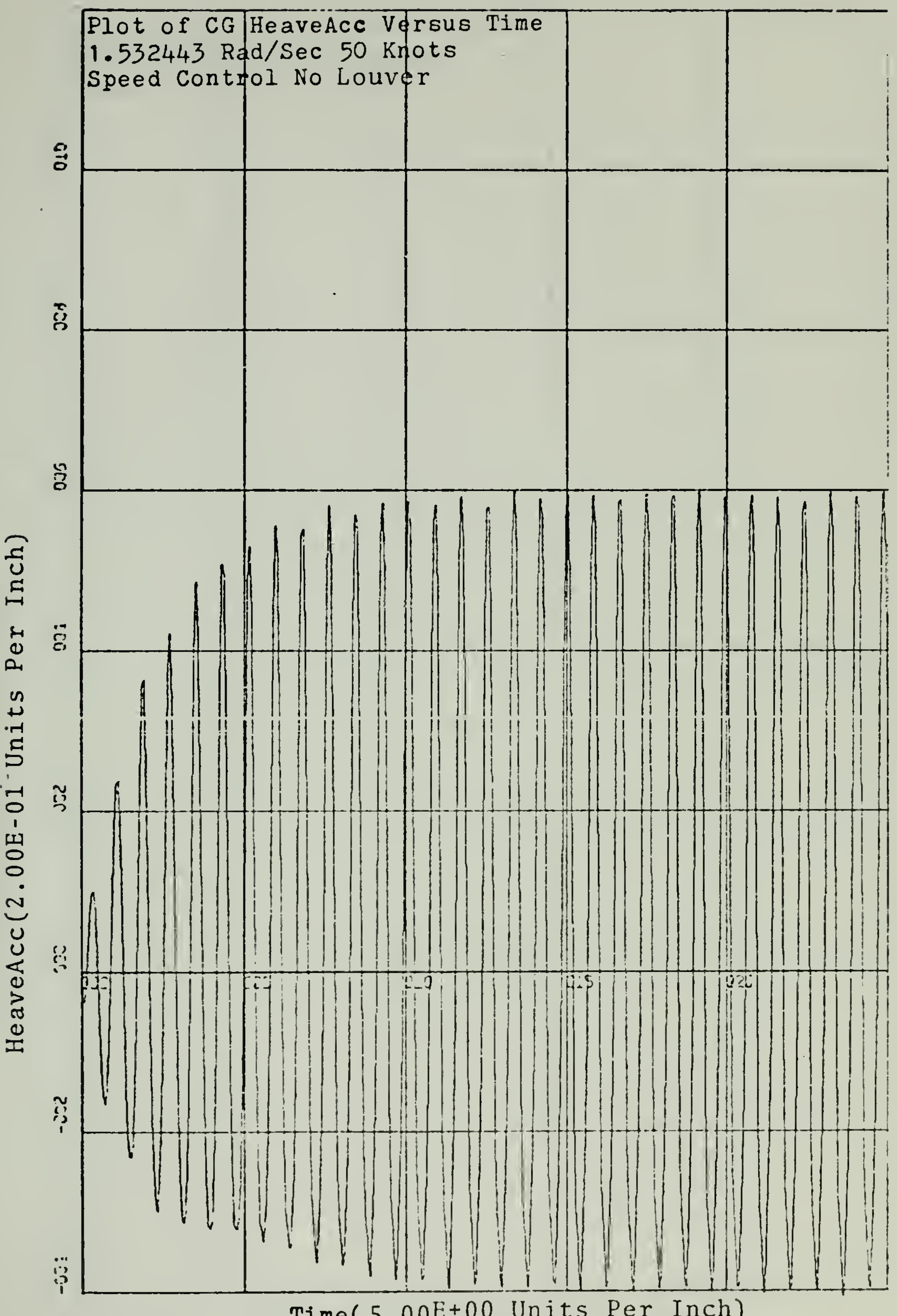
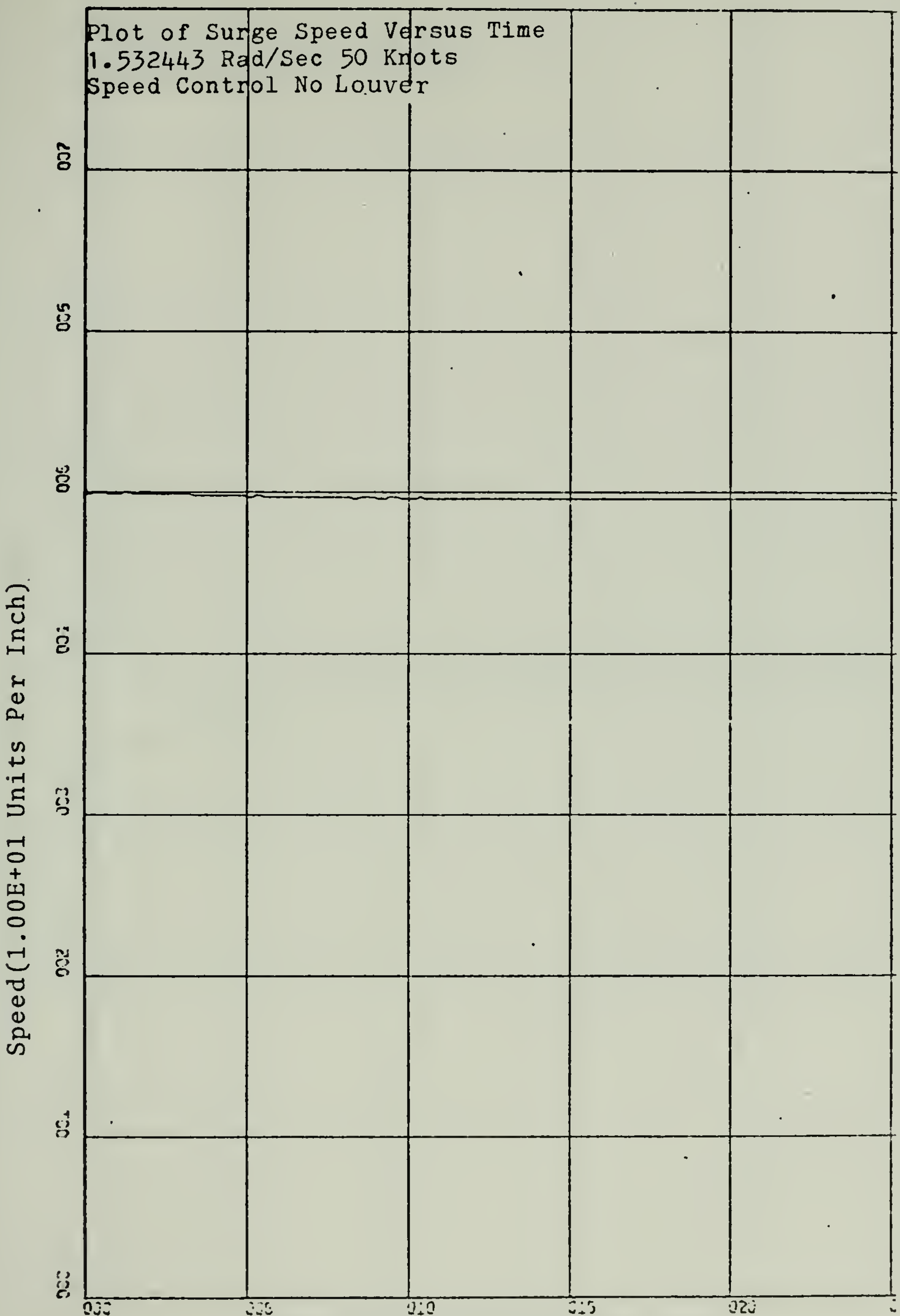
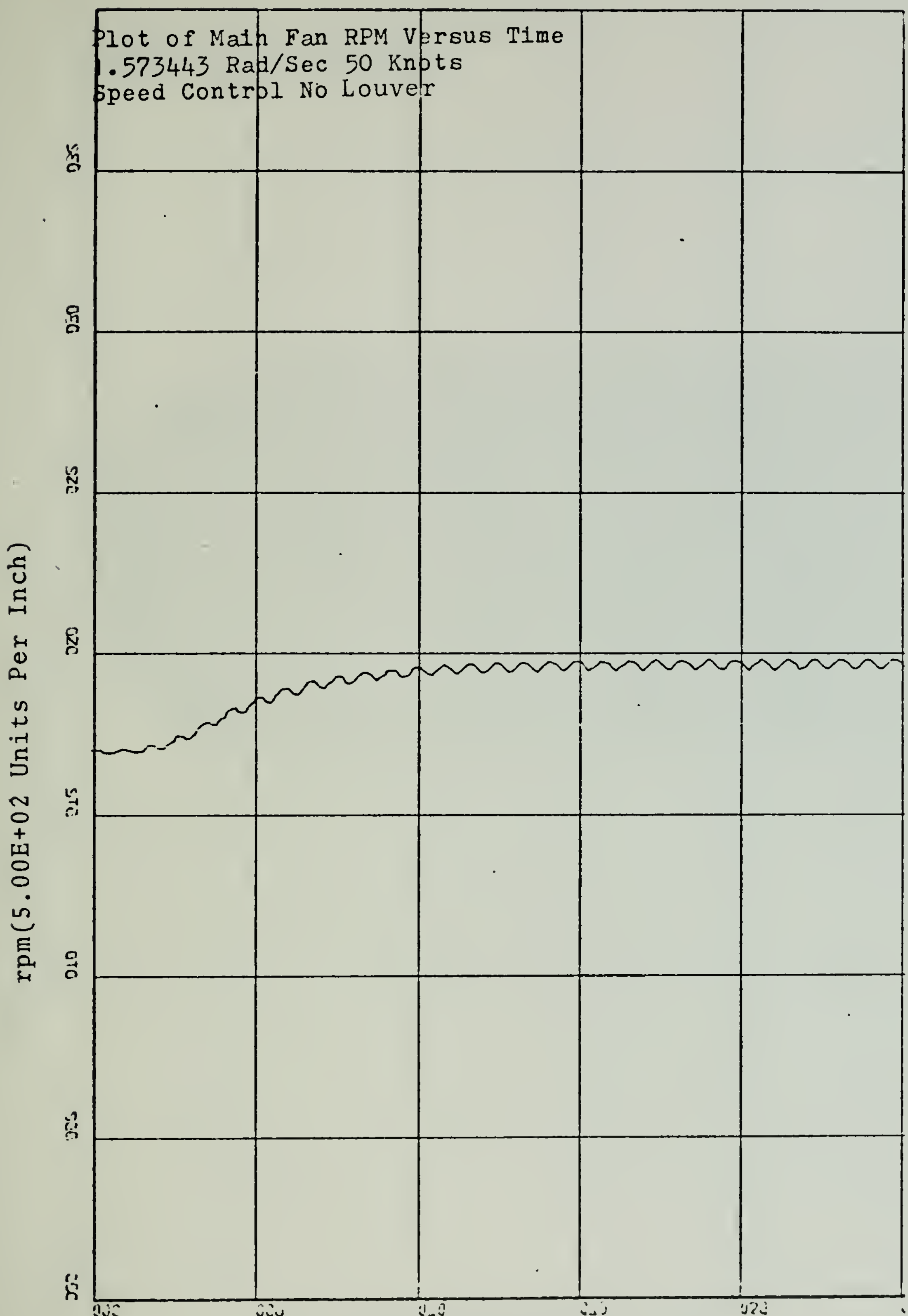

Plot of CG HeaveAcc Versus Time
1.532443 Rad/Sec 50 Knots
Speed Control No Louver
HeaveAcc(2.00E-01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 24



Plot of Surge Speed Versus Time
1.532443 Rad/Sec 50 Knots
Speed Control No Louver
Speed(1.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 25



Plot of Main Fan RPM Versus Time
.573443 Rad/Sec 50 Knots
Speed Control No Louver
rpm(5.00E+02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 27

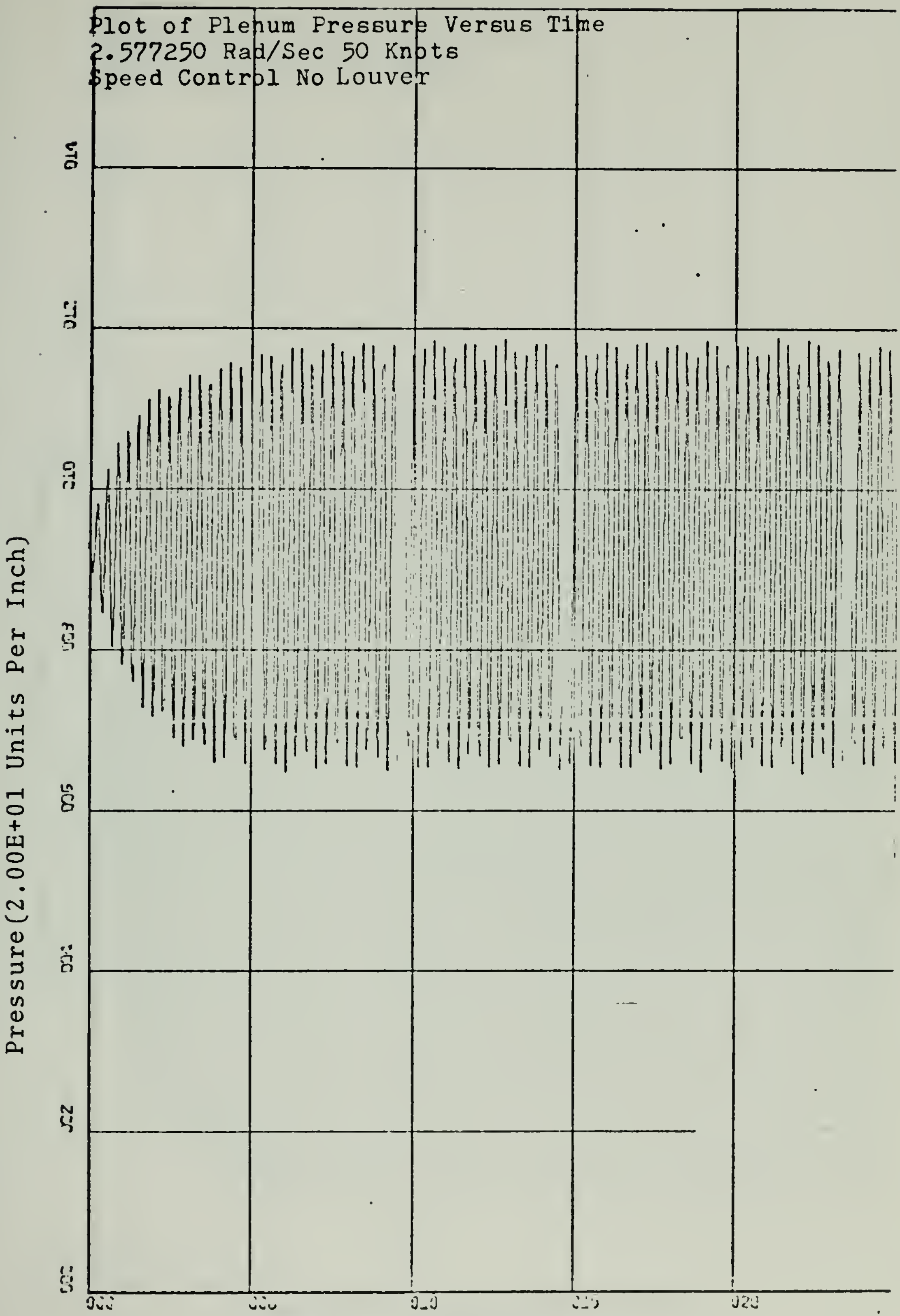
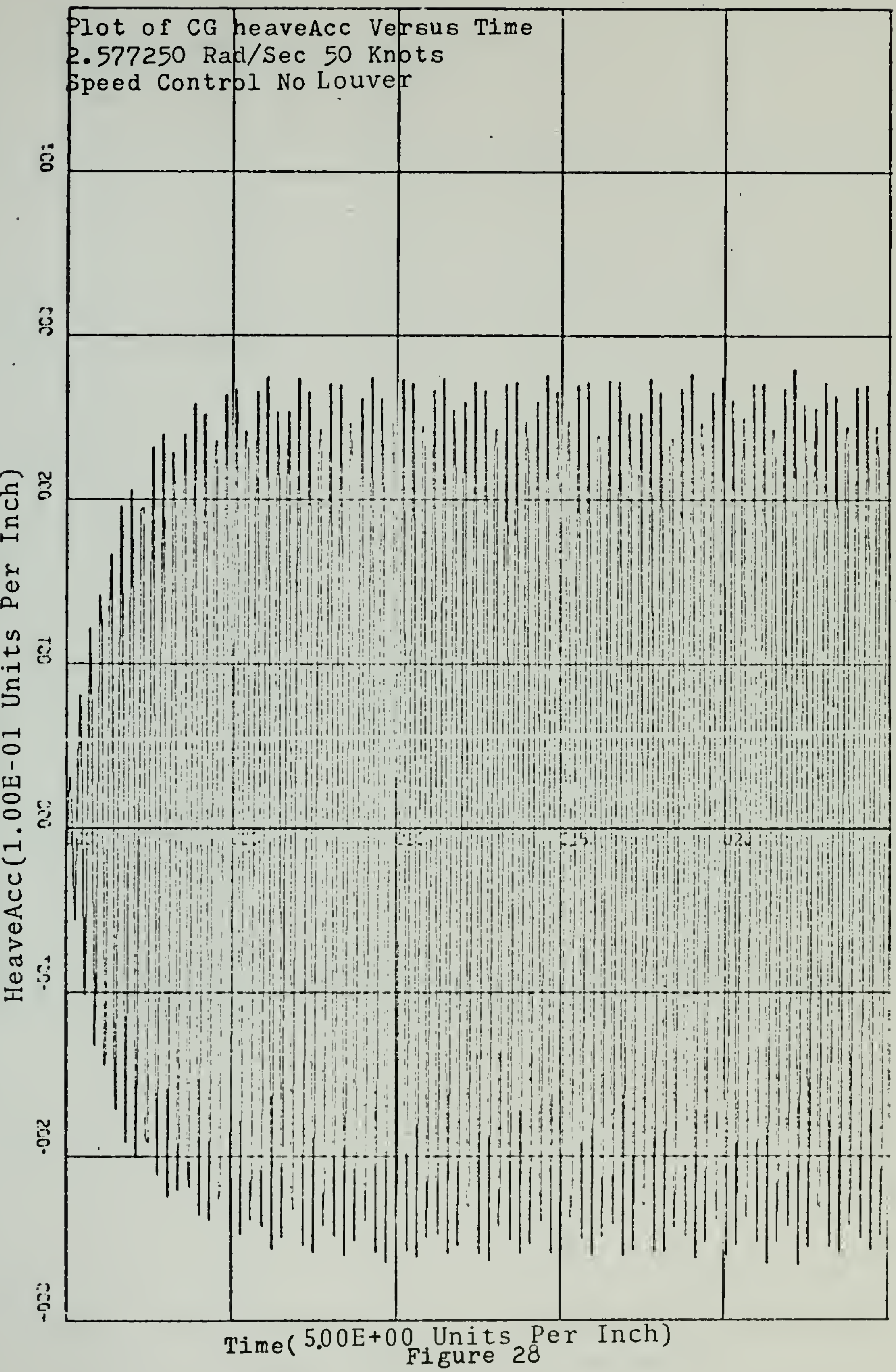

Plot of Plenum Pressure Versus Time
2.577250 Rad/Sec 50 Knots
Speed Control No Louver
Pressure(2.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 27


Plot of CG heaveAcc Versus Time
2.577250 Rad/Sec 50 Knots
Speed Control No Louver
HeaveAcc(1.00E-01 Units Per Inch)
Time(5.00E+00 Units Per Inch)
Figure 28

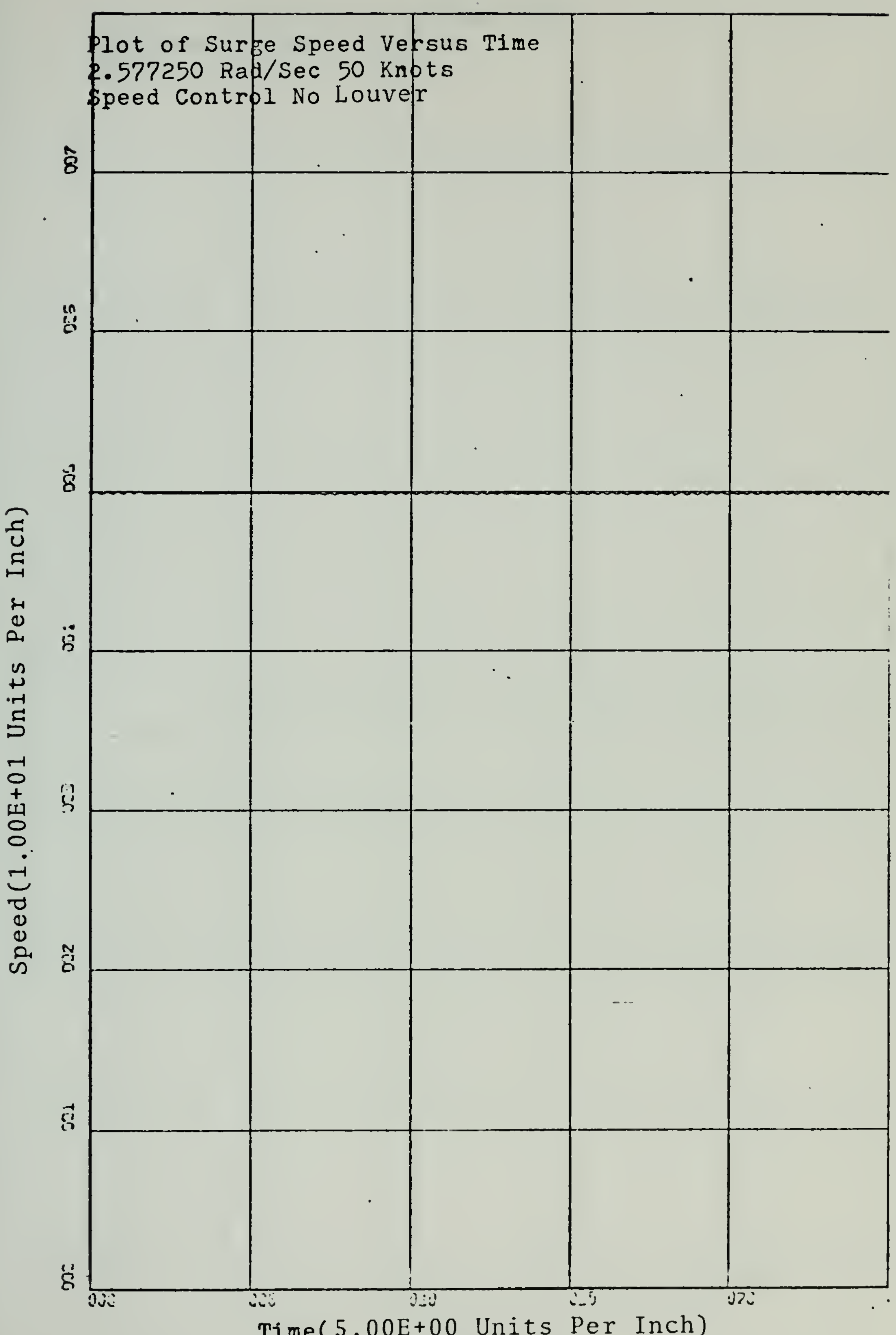
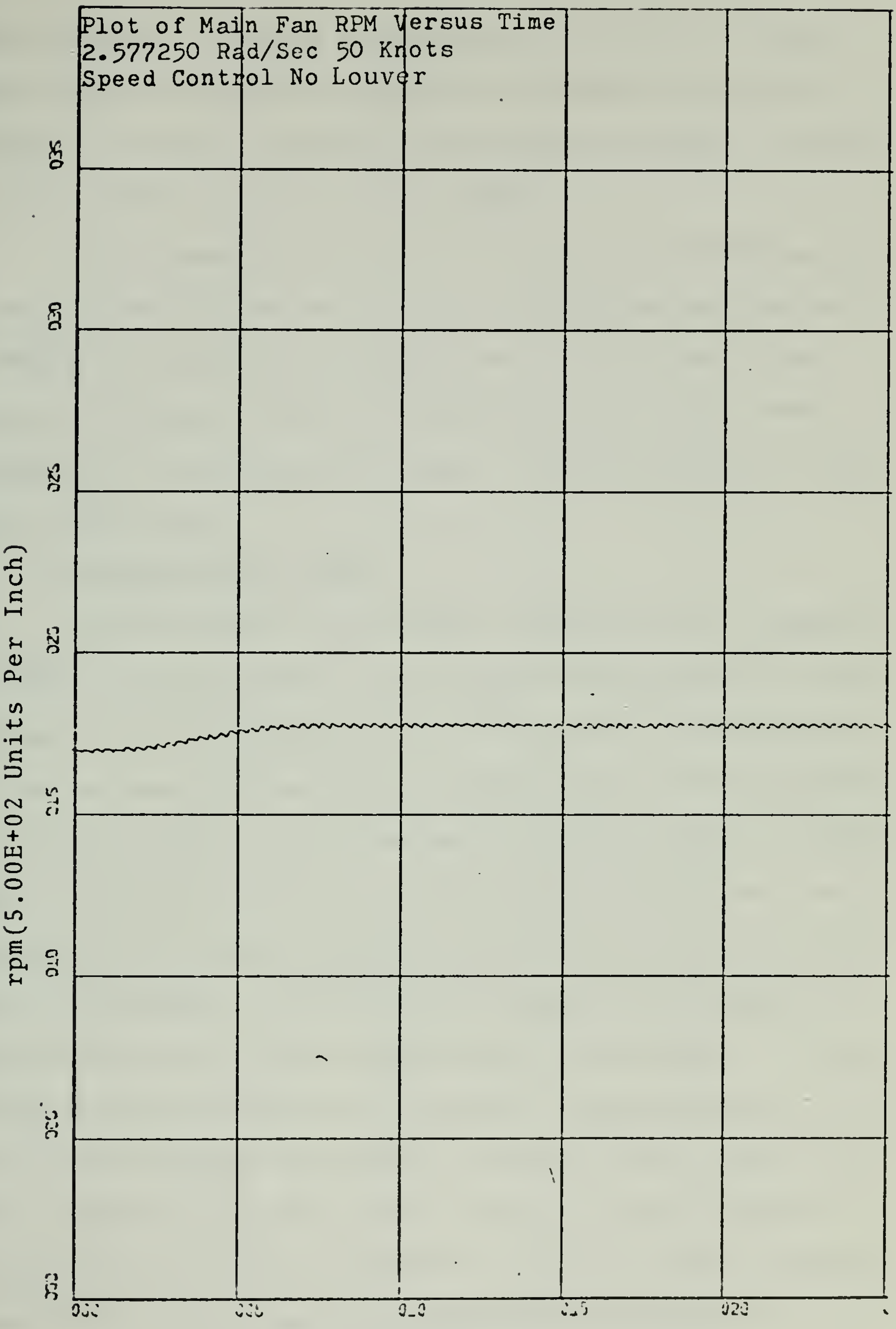

Plot of Surge Speed Versus Time
2.577250 Rad/Sec 50 Knots
Speed Control No Louver
Speed(1.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 29


Plot of Main Fan RPM Versus Time
2.577250 Rad/Sec 50 Knots
Speed Control No Louver
rpm(5.00E+02 Units Per Inch)
Time(5.00E+00 Units Per Inch)
Figure 30

acceleration. If waves encountered by the SES 100 were made of the two radian frequencies 0.766222 or 2.577250, probably the heave controller would not be needed. As can be seen later, this is not the case.

Both graphs which give the position of the louver do not directly give the area of venting but instead the strength of the signal to the louver. The size of the louver, in these studies, is sixteen feet by nine feet, multiplied by the position signal, quickly gives the total area of the vent.

3. <u>Heave Control Only</u>

After design of the heave controller was completed, computer runs were made at the same three frequencies with the same initial conditions. (See Figures 31 through 45.) As can be seen a great deal of reduction in heave acceleration can be noted. This can be misleading unless the other data presented is placed in the proper perspective. Because of the venting created by the louvers, more air than can be replaced by the fans has escaped and although it appears that the plenum pressure has steadied out. A look at the surge speed shows a continual slowing process as the draft of the craft continues to increase (not shown). In other computer runs not shown of more violent seas, the craft quickly settled beyond the value which the simulation model could handle and the program was terminated.

4. <u>Heave Control with Velocity Difference Loop</u>

When the velocity difference loop was inserted with the heave controller, the overall results were quite good.

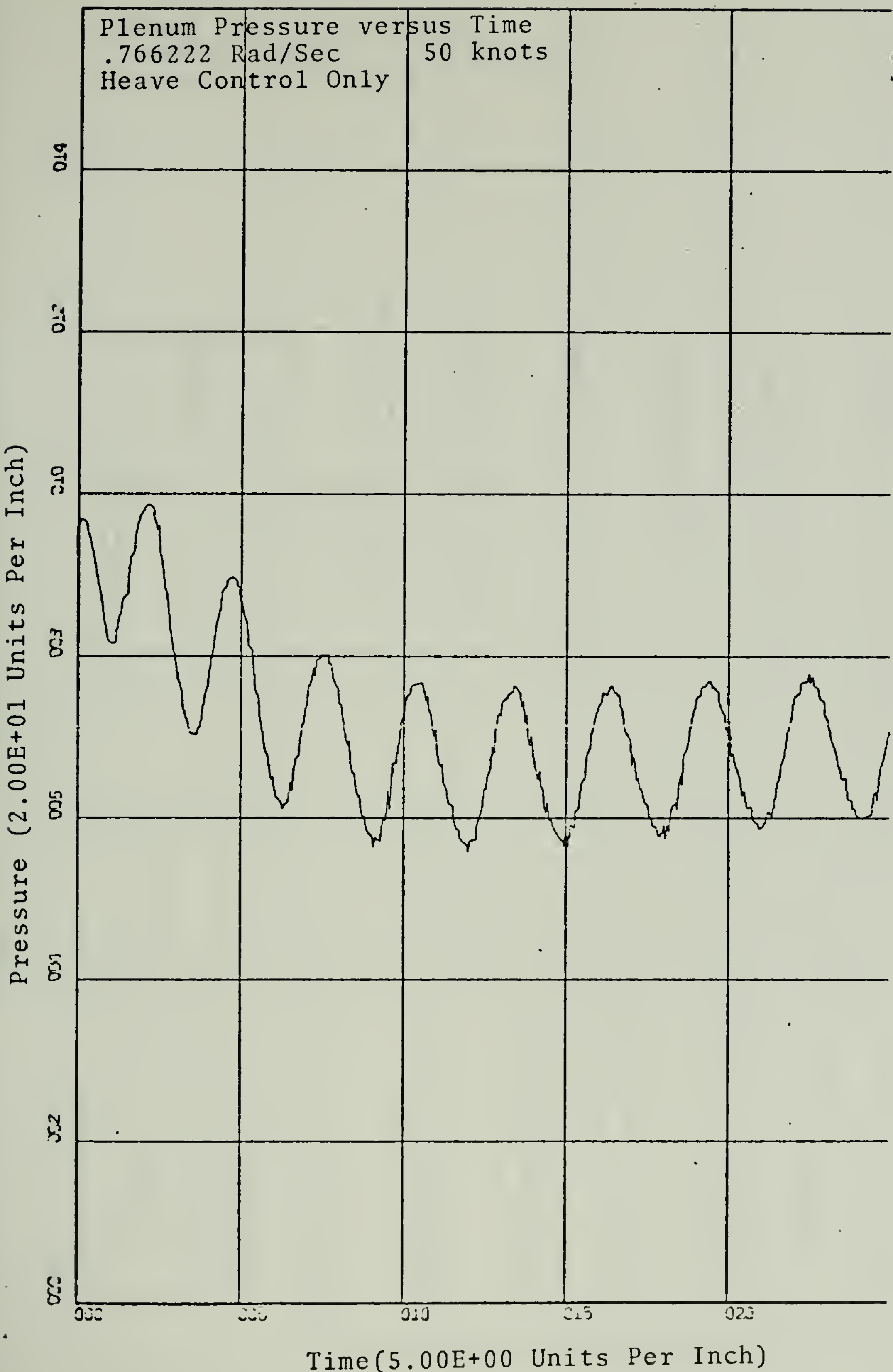

Plenum Pressure versus Time
.766222 Rad/Sec
50 knots
Heave Control Only
Pressure (2.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 31.

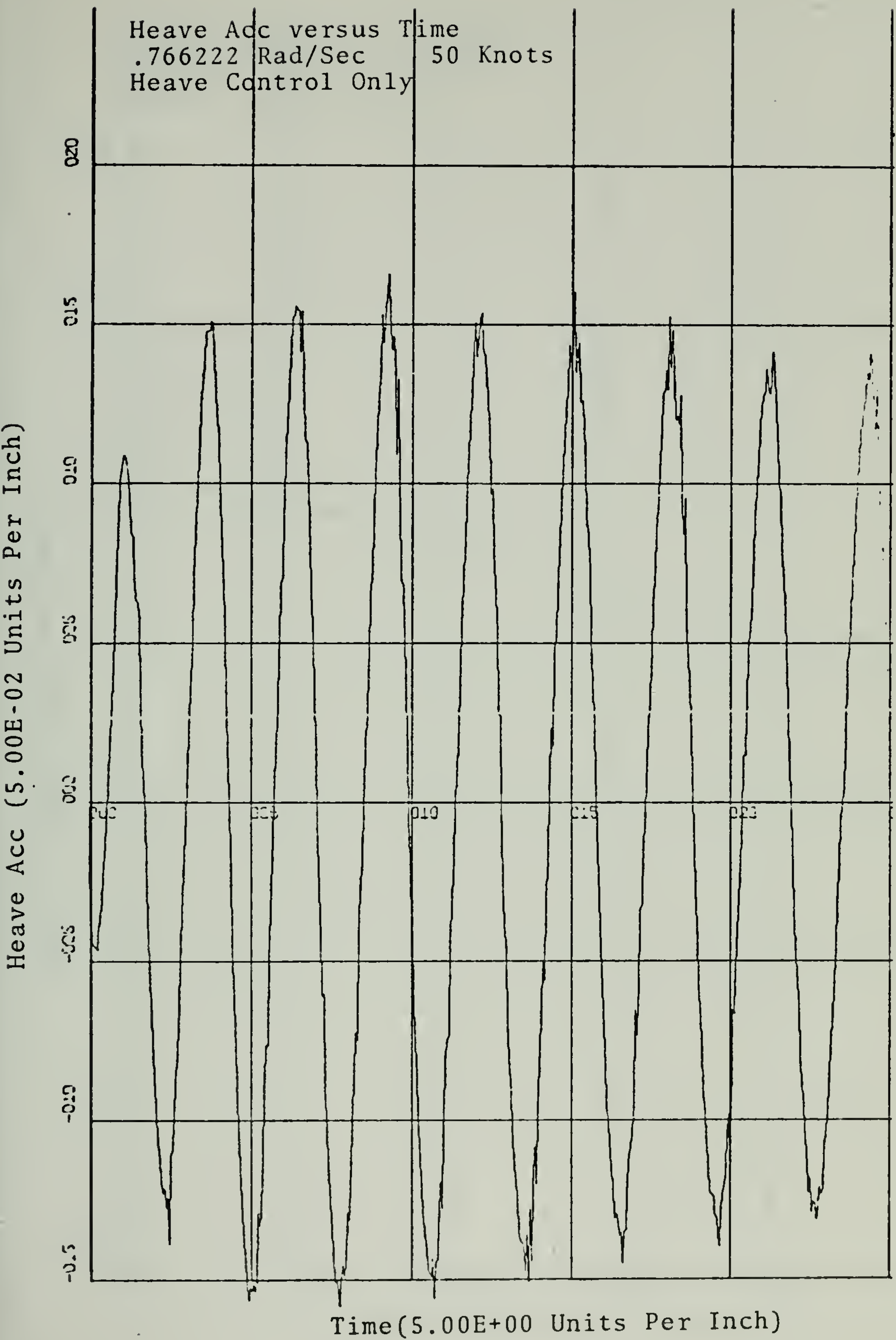

Heave Acc versus Time
.766222 Rad/Sec 50 Knots
Heave Control Only
Heave Acc (5.00E-02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 32.

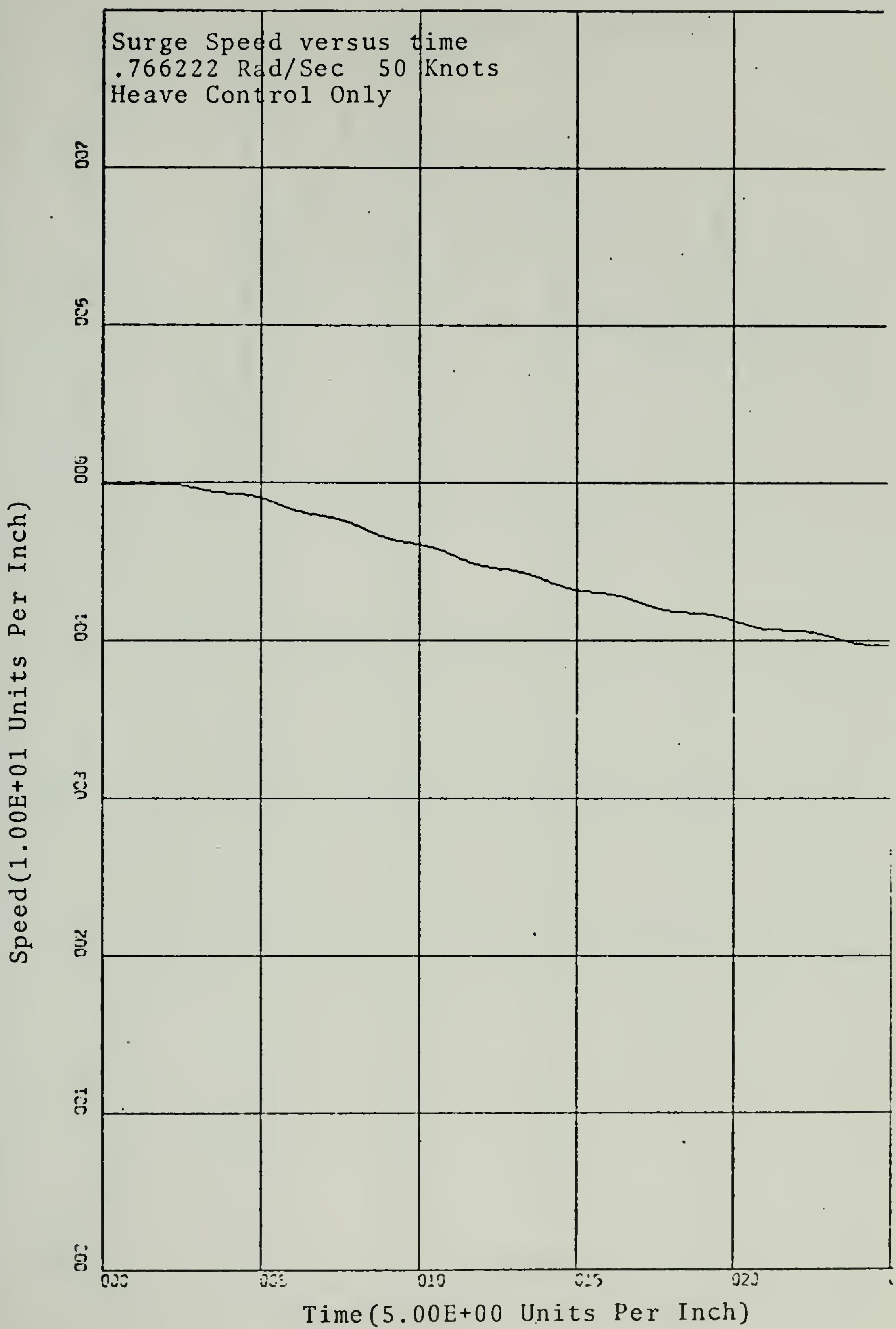

Surge Speed versus time
.766222 Rad/Sec 50 Knots
Heave Control Only
Speed(1.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 33.

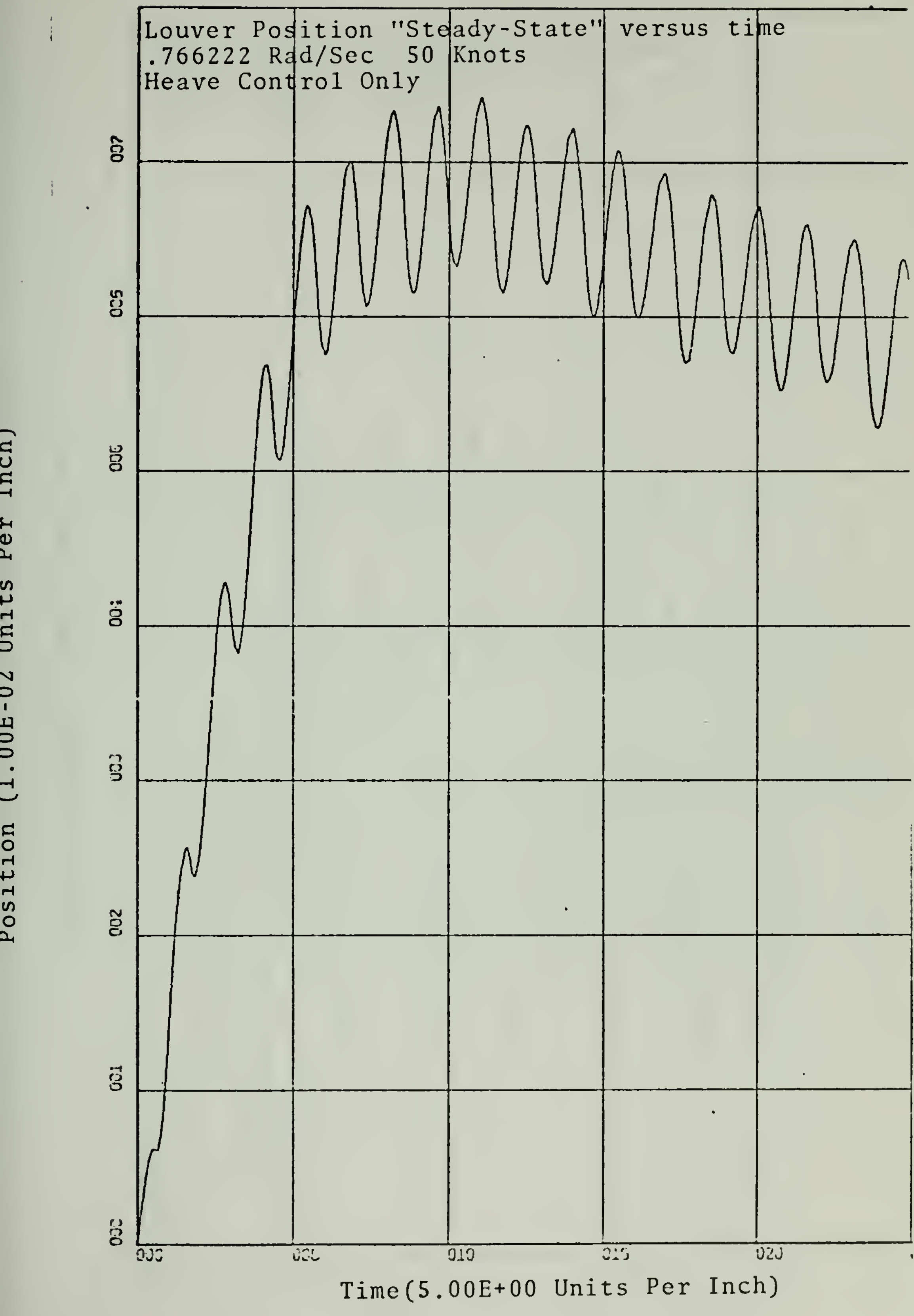

Louver Position "Steady-State" versus time
.766222 Rad/Sec 50 Knots
Heave Control Only
Position (1.00E-02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 34.

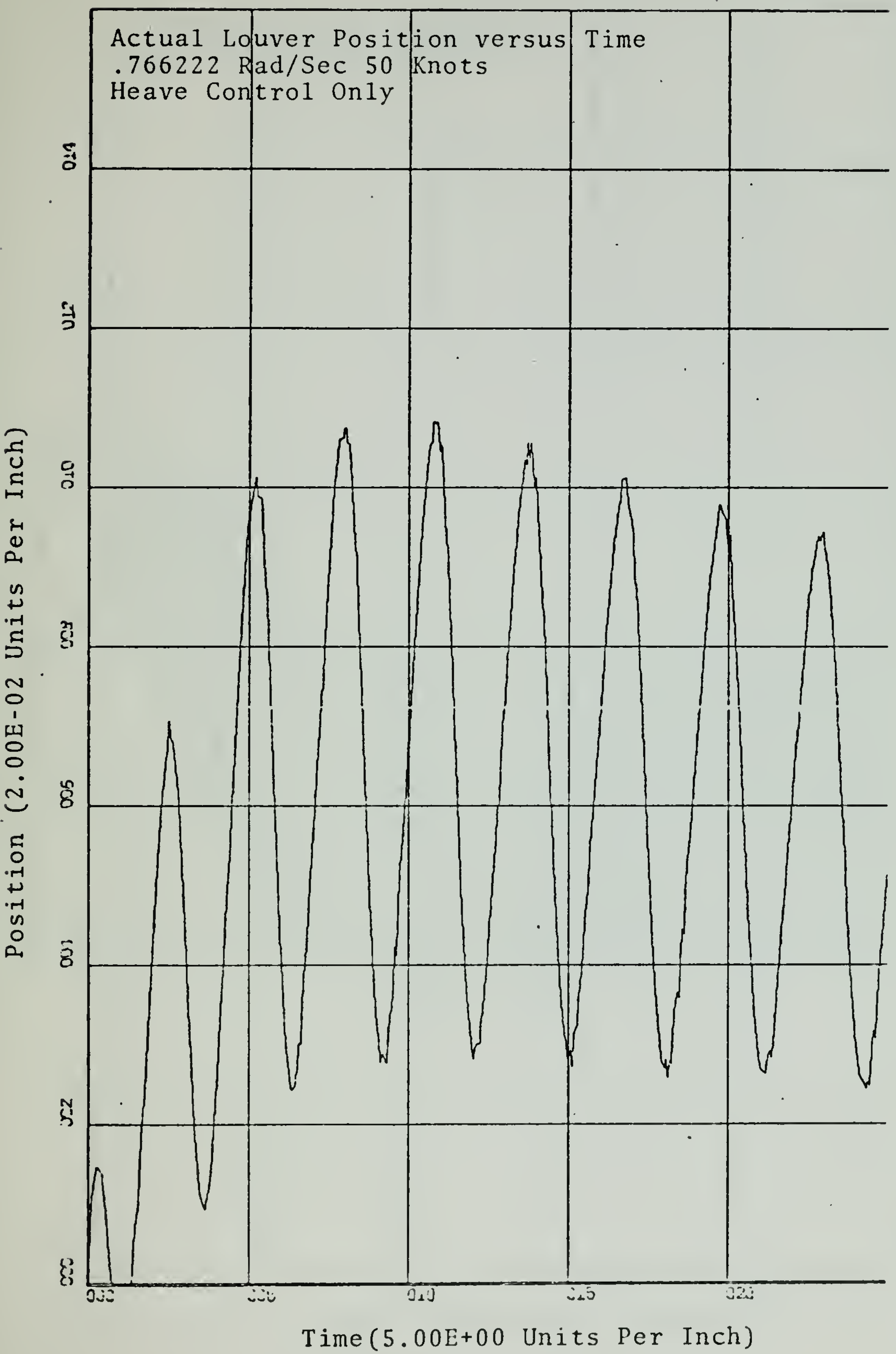

Actual Louver Position versus Time
.766222 Rad/Sec 50 Knots
Heave Control Only
Position (2.00E-02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 35.

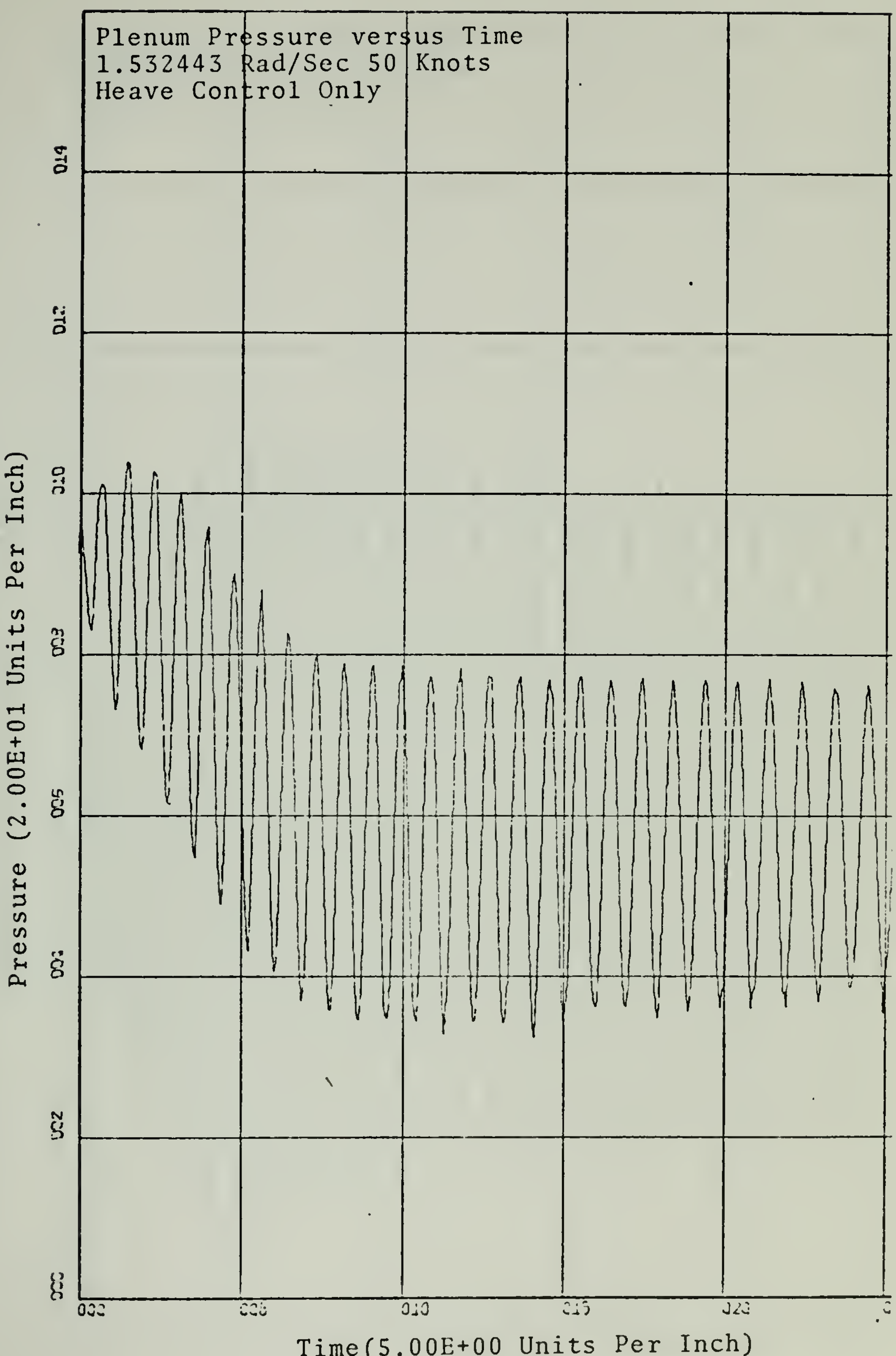

Plenum Pressure versus Time
1.532443 Rad/Sec 50 Knots
Heave Control Only
Pressure (2.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 36.

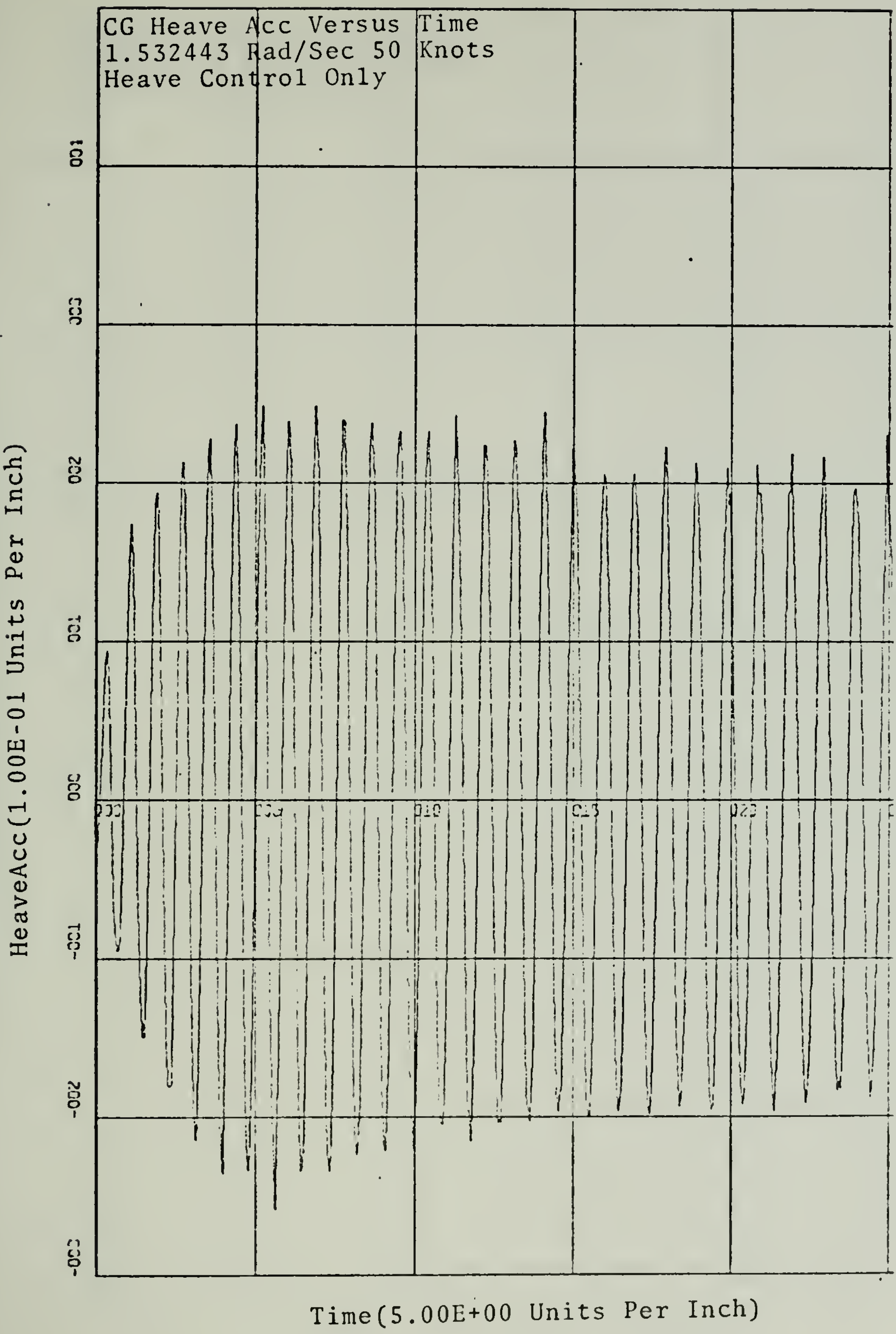

CG Heave Acc Versus Time
1.532443 Rad/Sec 50 Knots
Heave Control Only
HeaveAcc(1.00E-01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 37.

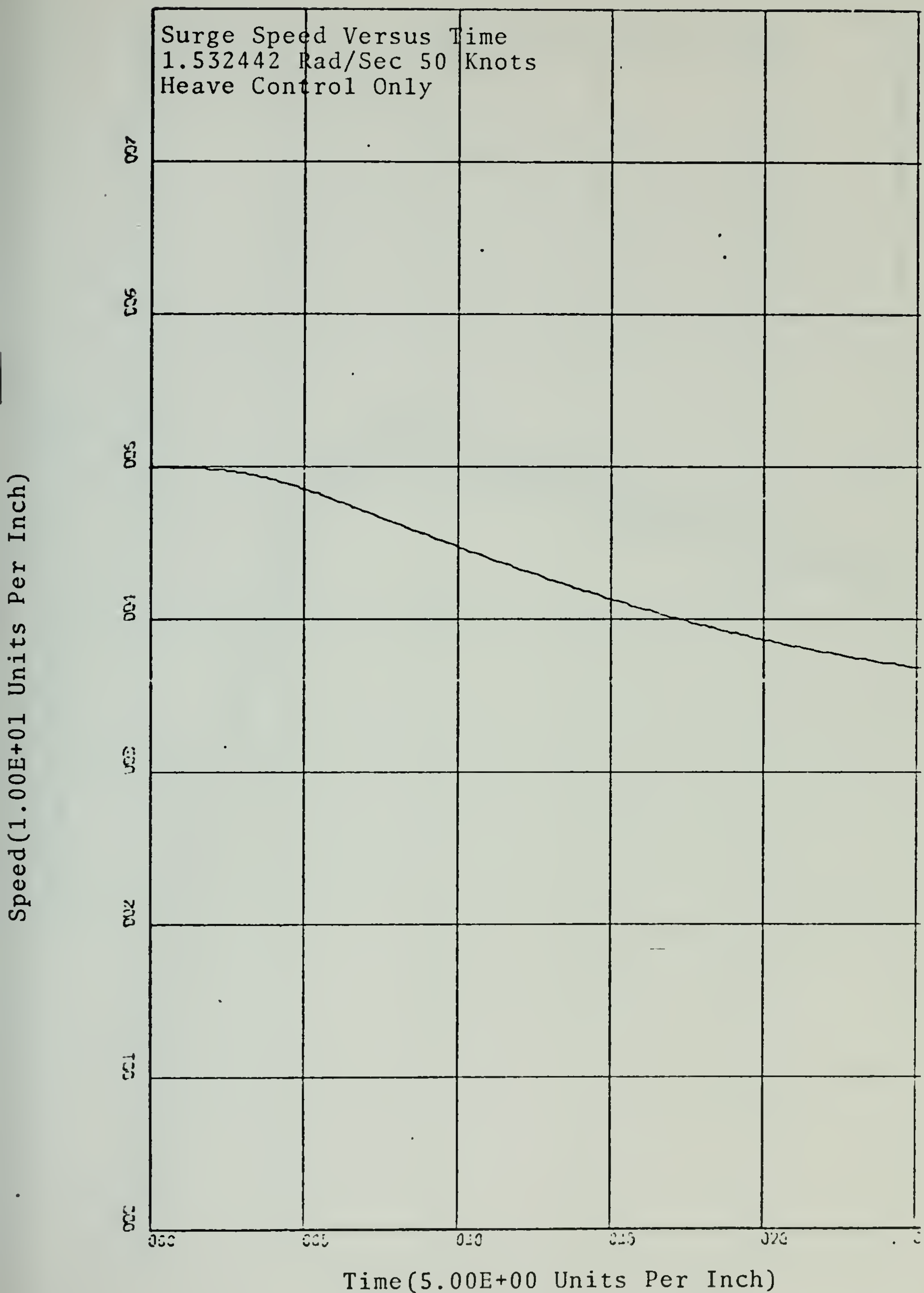

Surge Speed Versus Time
1.532442 Rad/Sec 50 Knots
Heave Control Only
Speed(1.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 38.

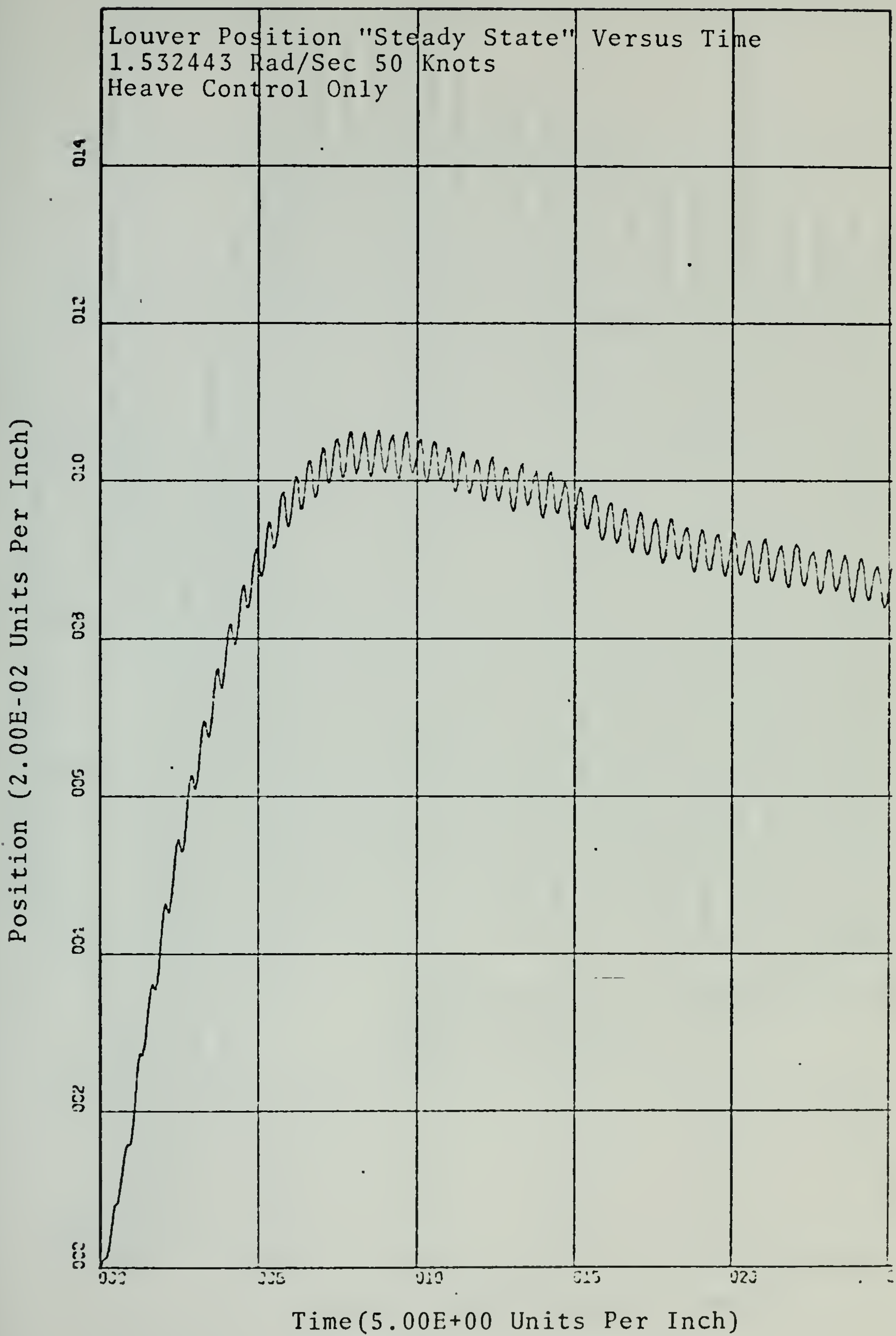

Louver Position "Steady State" Versus Time
1.532443 Rad/Sec 50 Knots
Heave Control Only
Position (2.00E-02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 39.

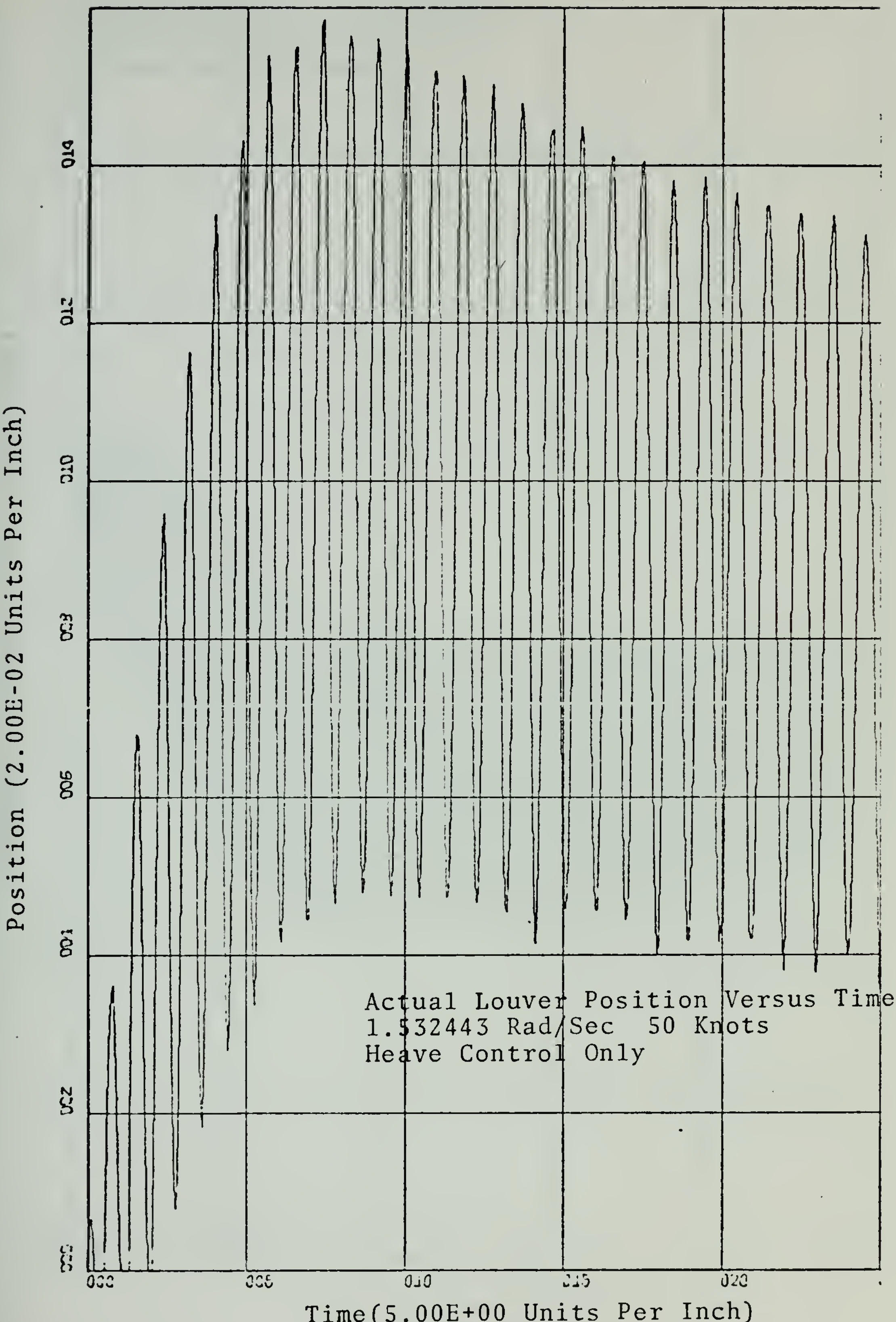

Position (2.00E-02 Units Per Inch)
Time(5.00E+00 Units Per Inch)
Actual Louver Position Versus Time
1.532443 Rad/Sec 50 Knots
Heave Control Only

Figure 40.

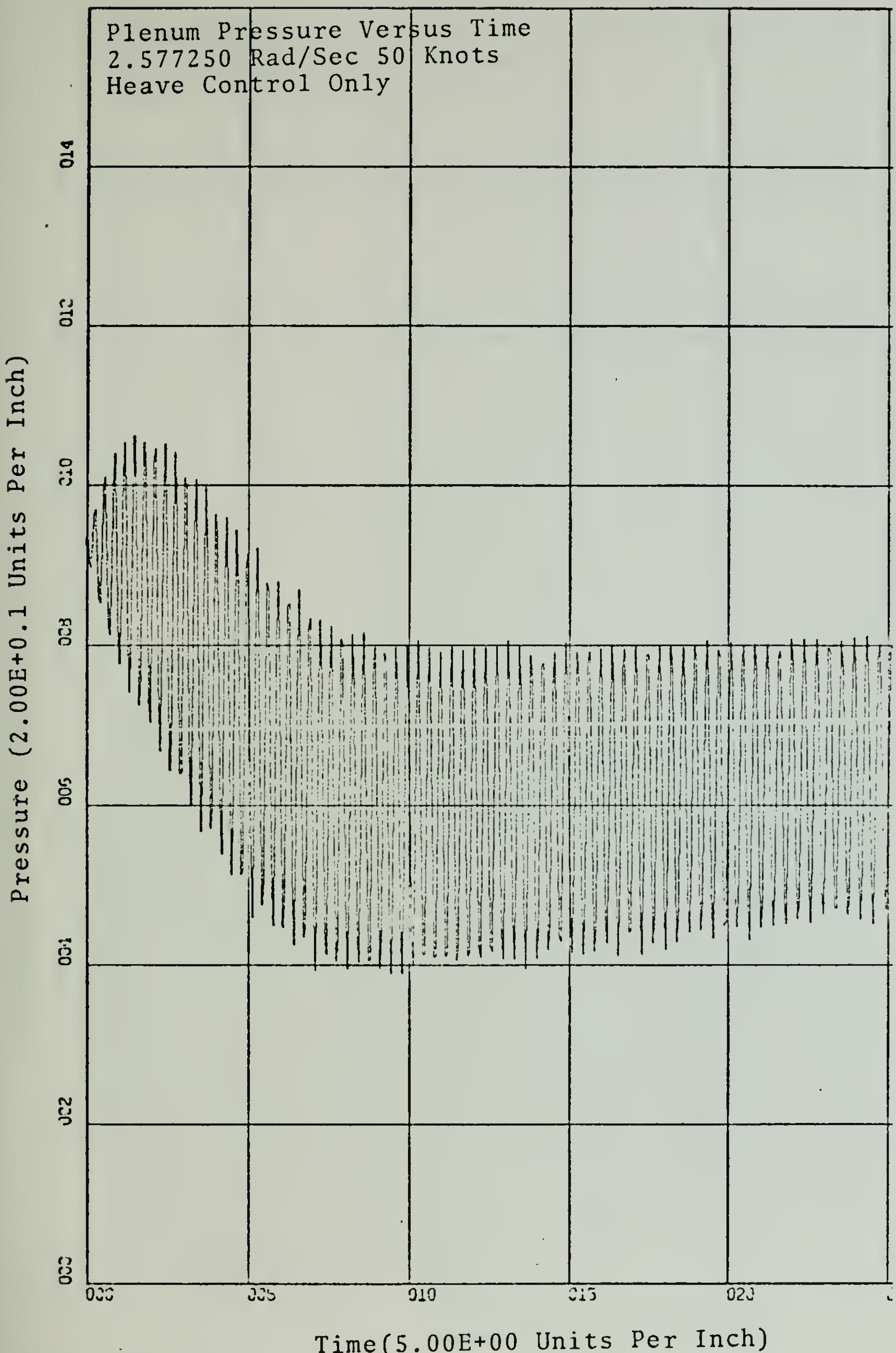

Plenum Pressure Versus Time
2.577250 Rad/Sec 50 Knots
Heave Control Only
Pressure (2.00E+0.1 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 41.

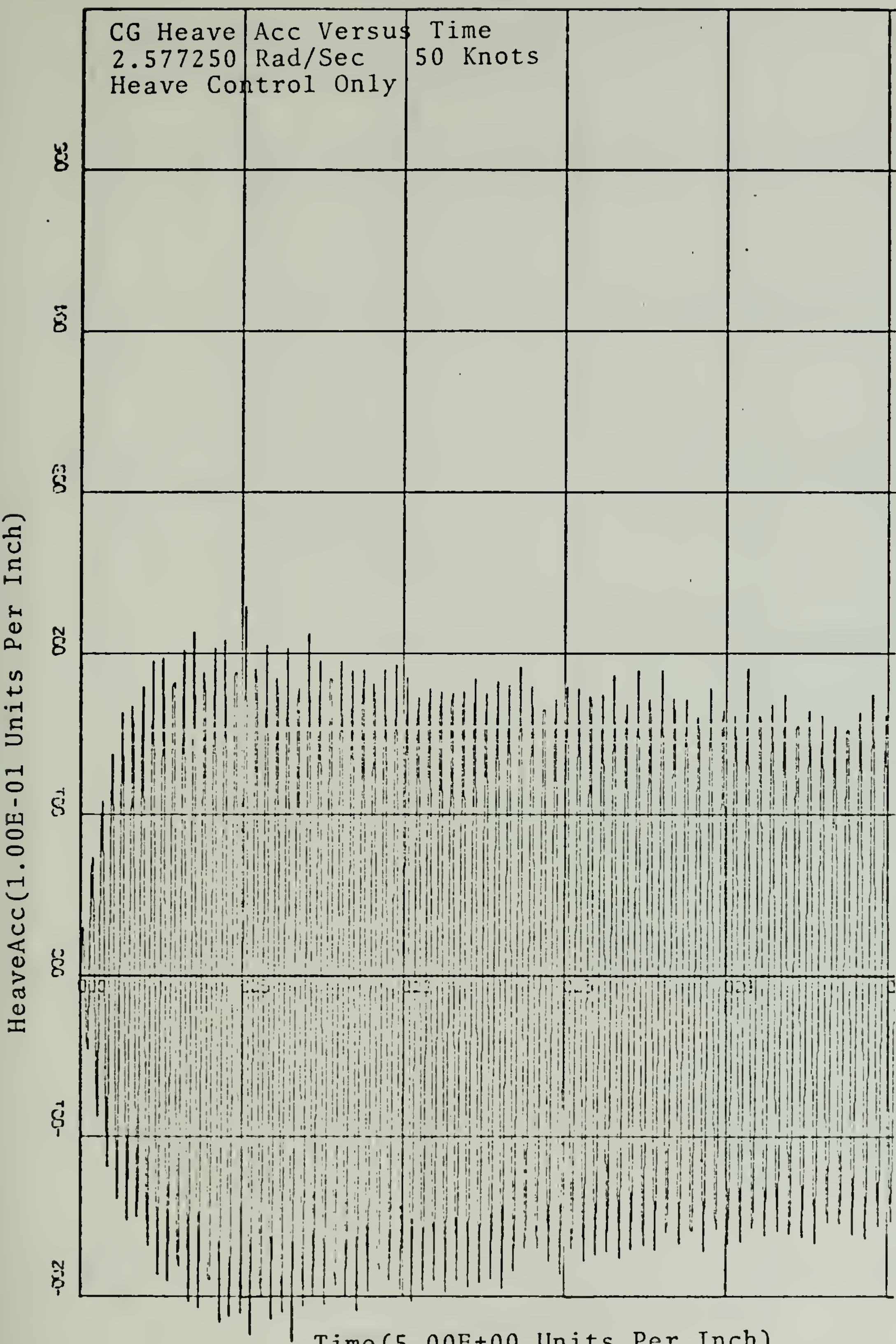

CG Heave Acc Versus Time
2.577250 Rad/Sec 50 Knots
Heave Control Only
HeaveAcc(1.00E-01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 42.

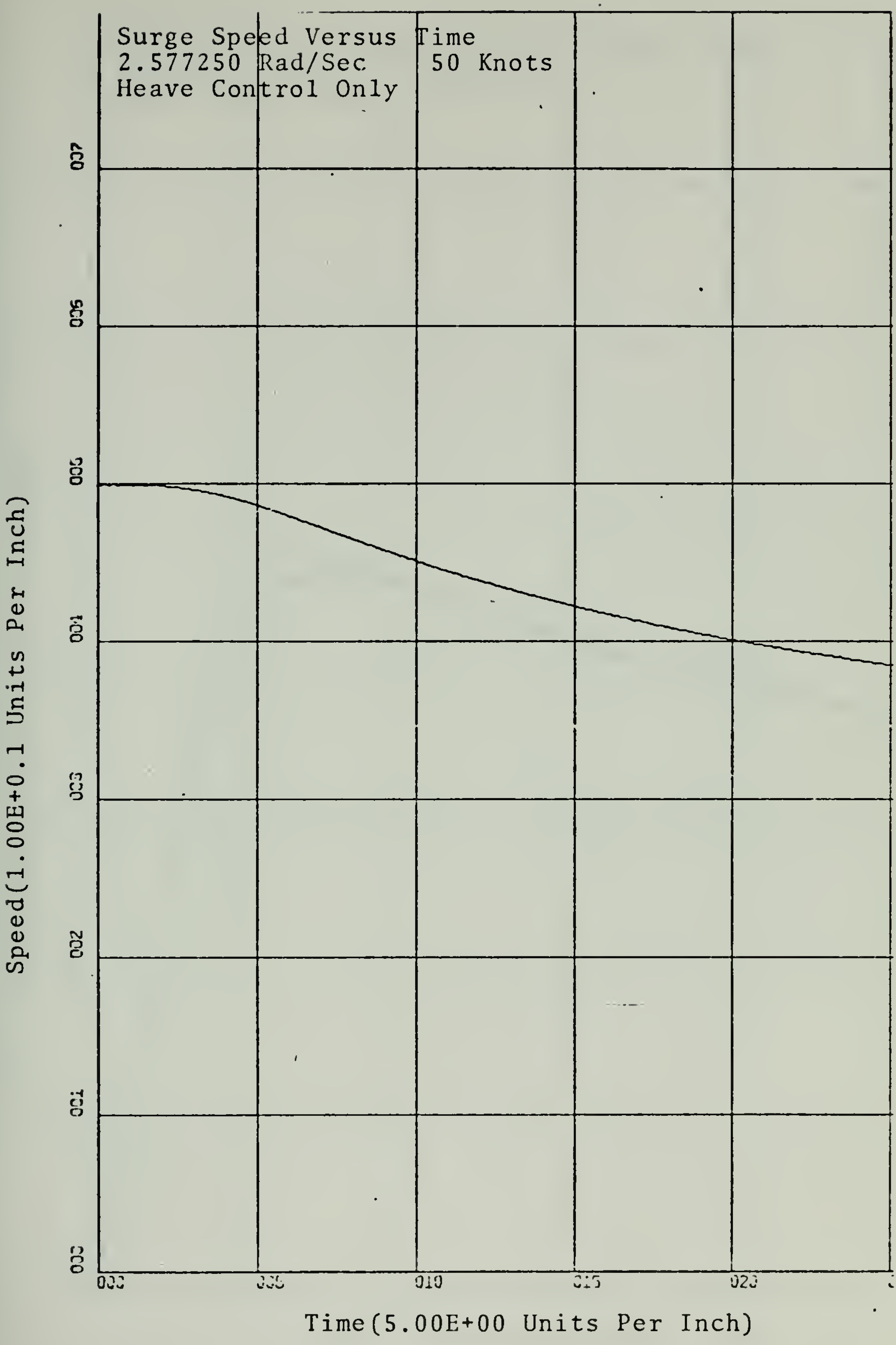

Surge Speed Versus Time
2.577250 Rad/Sec
50 Knots
Heave Control Only
Speed(1.00E+0.1 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 43.

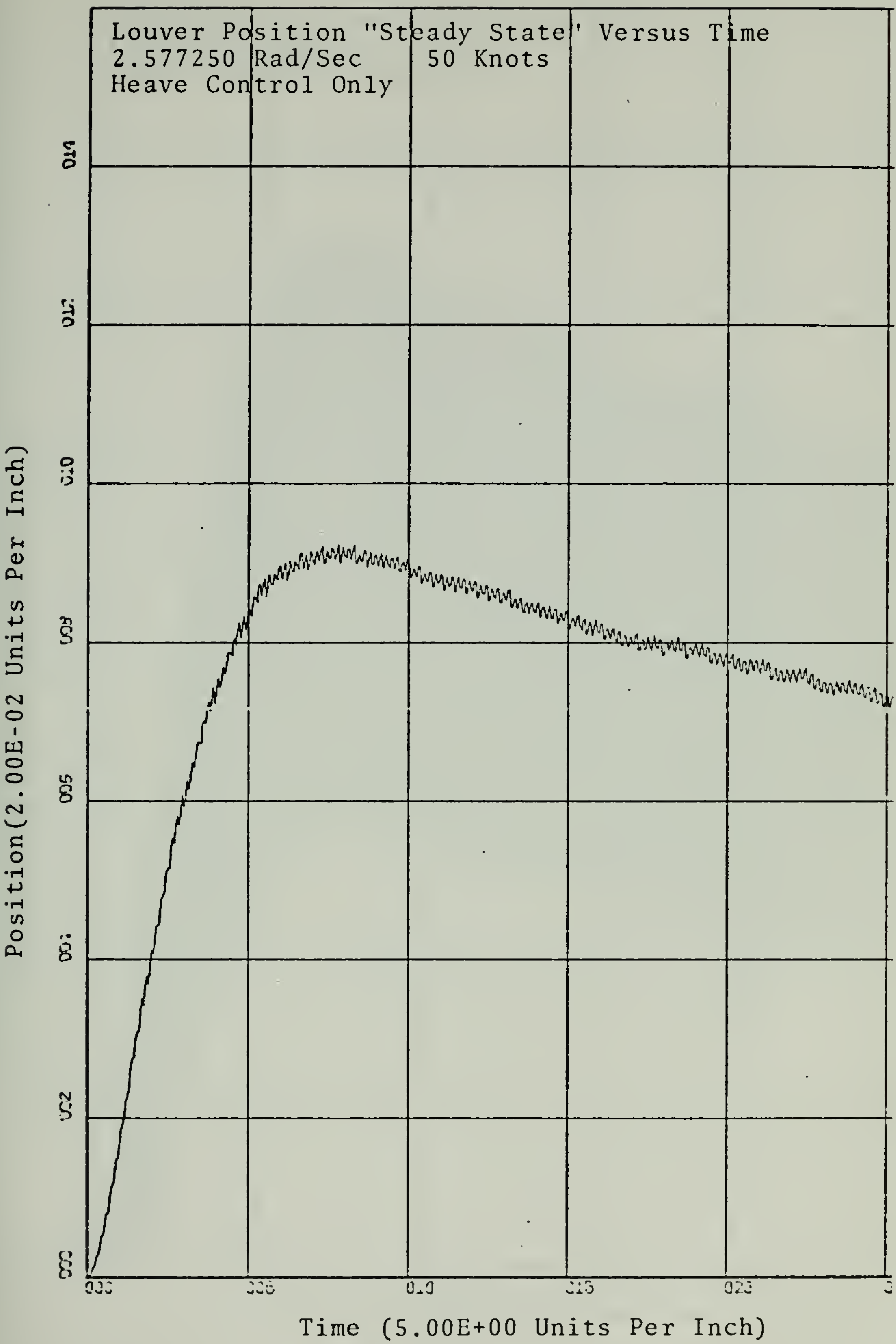
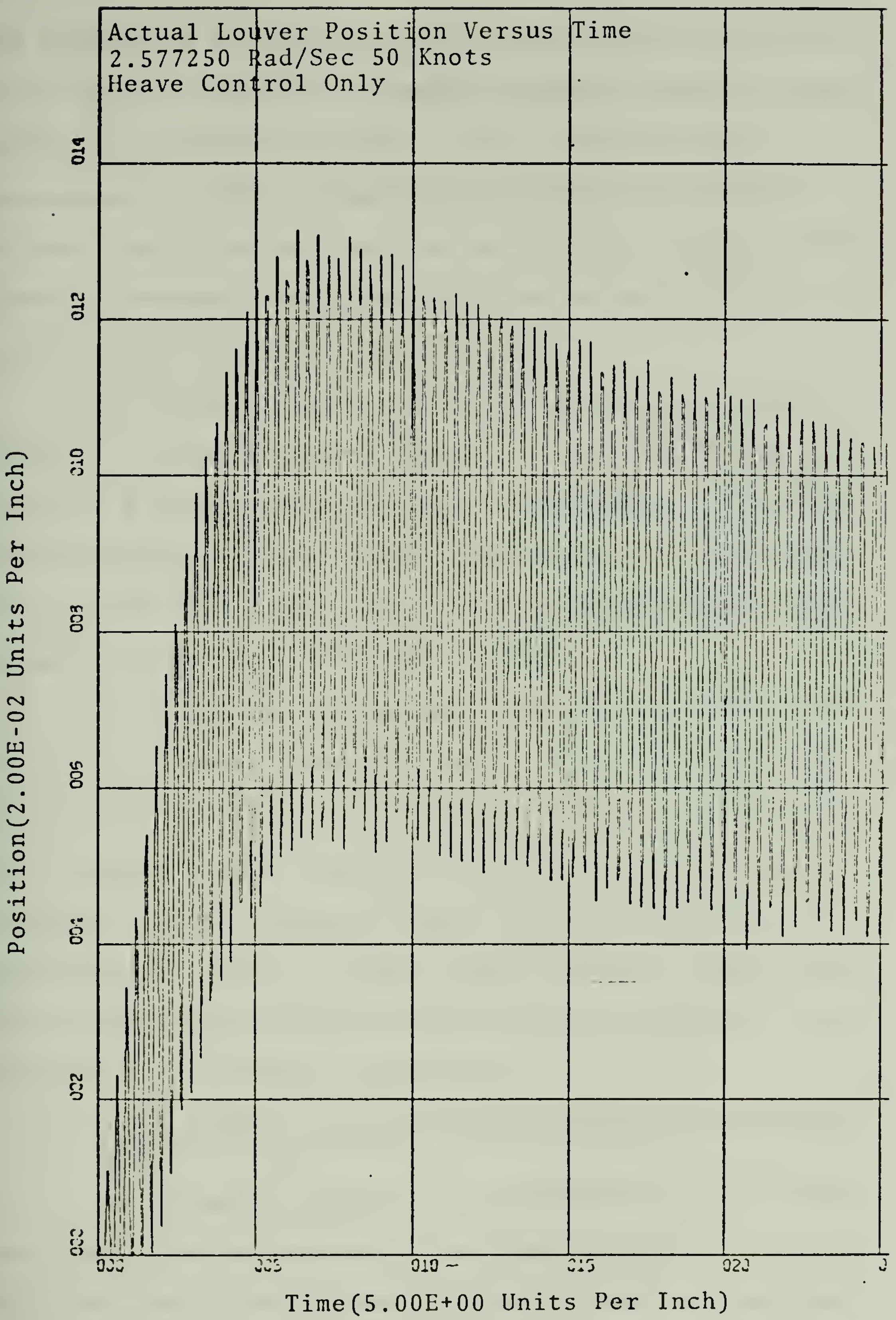

Louver Position "Steady State" Versus Time
2.577250 Rad/Sec 50 Knots
Heave Control Only
Position(2.00E-02 Units Per Inch)
Time (5.00E+00 Units Per Inch)

Figure 44.



Actual Louver Position Versus Time
2.577250 Rad/Sec 50 Knots
Heave Control Only
Position(2.00E-02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 45.

(See Figures 46 through 60.) Not only did the forward velocity reach a reasonable steady-state value but the heave accelerations dropped sharply. For 1.532443 rad/sec, an improvement of fifty percent over the speed loop alone and even thirty percent over the no controls run was noted. Marked improvements in heave acceleration can be seen in the other two frequencies also.

Not being satisfied with the steady-state speeds, the gain, k_3, was increased several times over trying to arrive at a steady-state velocity approaching .1 of a knot of the initial velocity rather than about 1.8 as is shown here in this data. When the gain was increased, the rpm increased as did the heave acceleration.

Up to this point the wave parameters utilized for this study produced relatively small heave accelerations. From analysis of the data up to this point, it became evident that the simple velocity difference loop by itself, although it performed beautifully at this time, was not sufficient for waves of larger amplitudes and studies with sea states and further investigations continued with a different type of velocity controller.

5. Heave Control with the Completed Velocity Control Loop

The results taken for the controller in its final form, while not as impressive as those recorded in the previous section as far as heave accelerations are concerned show dramatic improvement in speed control. (See Figures 61 through 77.) Heave acceleration is still acceptable and

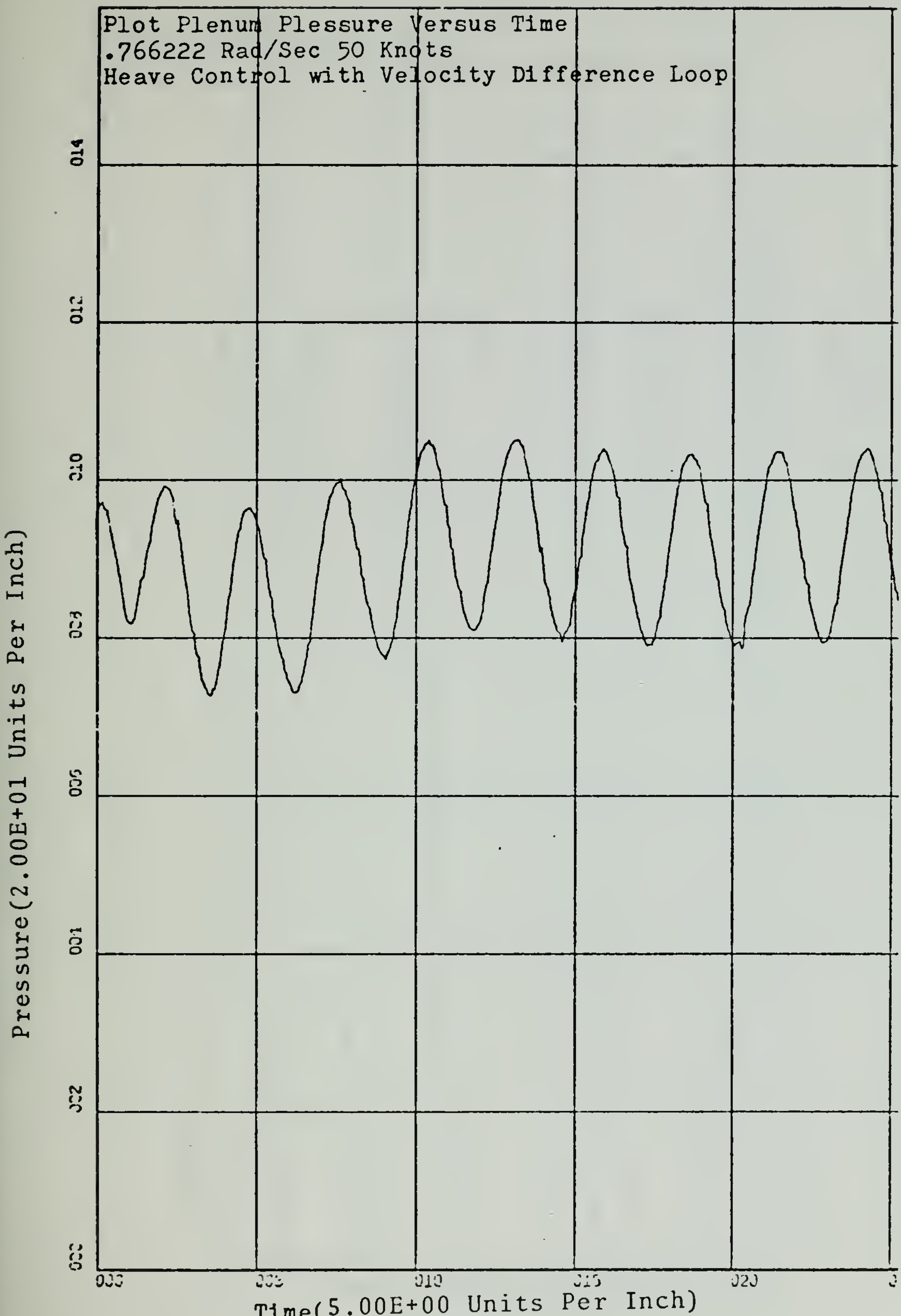

Plot Plenum Plessure Versus Time
.766222 Rad/Sec 50 Knots
Heave Control with Velocity Difference Loop
Pressure(2.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 46

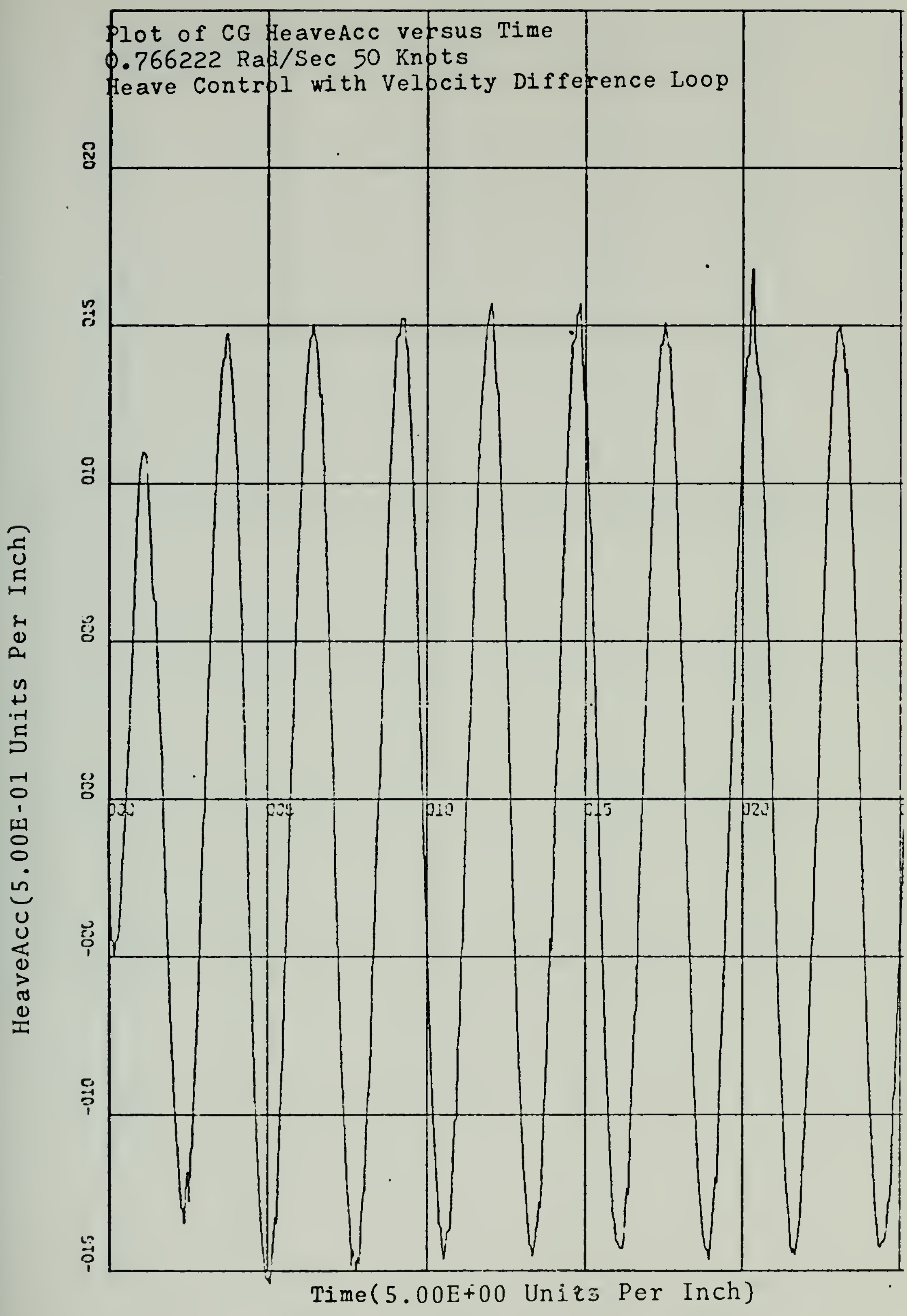

Plot of CG HeaveAcc versus Time
0.766222 Rad/Sec 50 Knots
Heave Control with Velocity Difference Loop
HeaveAcc(5.00E-01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 47.

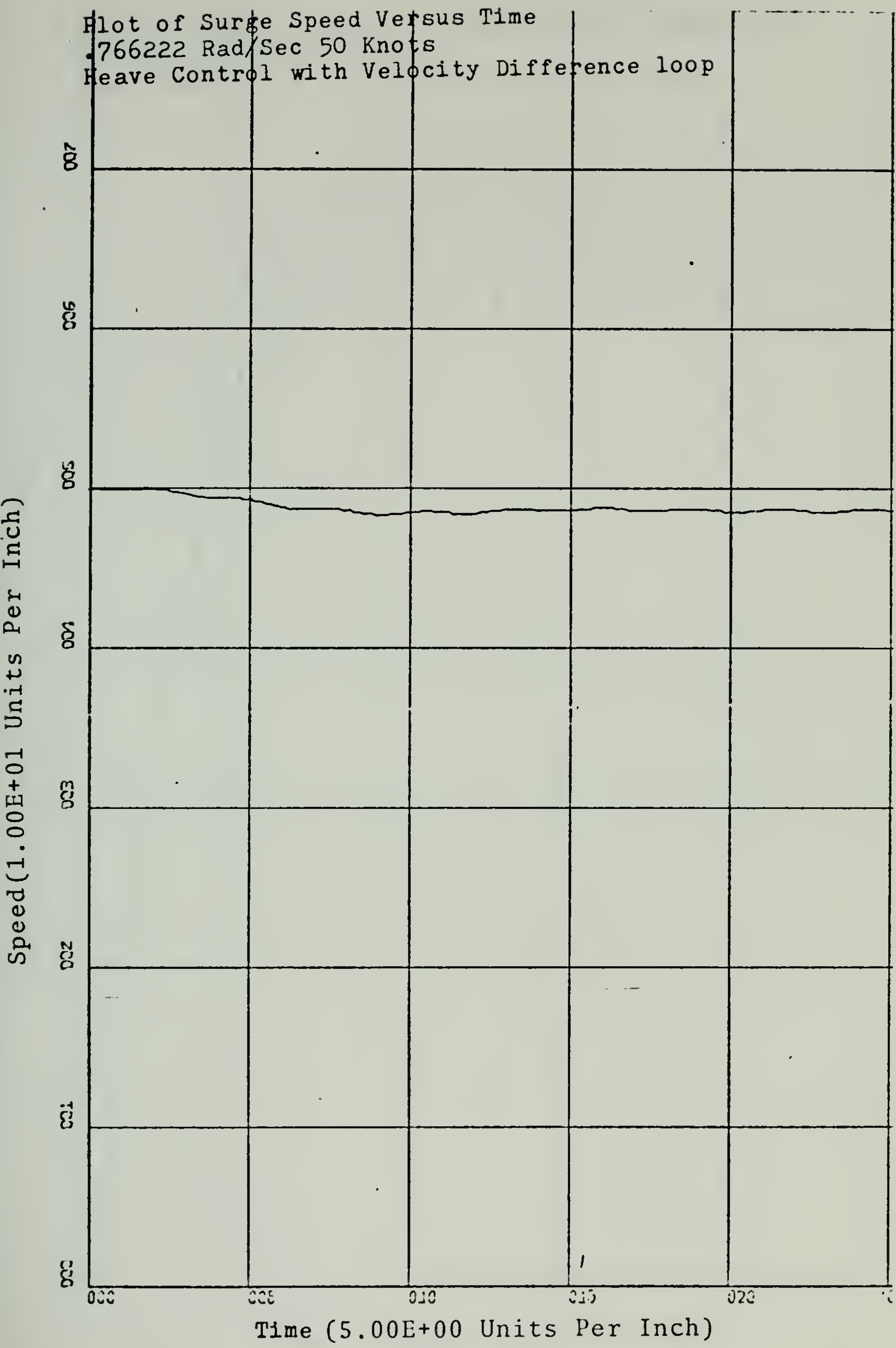

Plot of Surge Speed Versus Time
.766222 Rad/Sec 50 Knots
Heave Control with Velocity Difference loop
Speed(1.00E+01 Units Per Inch)
Time (5.00E+00 Units Per Inch)

Figure 49

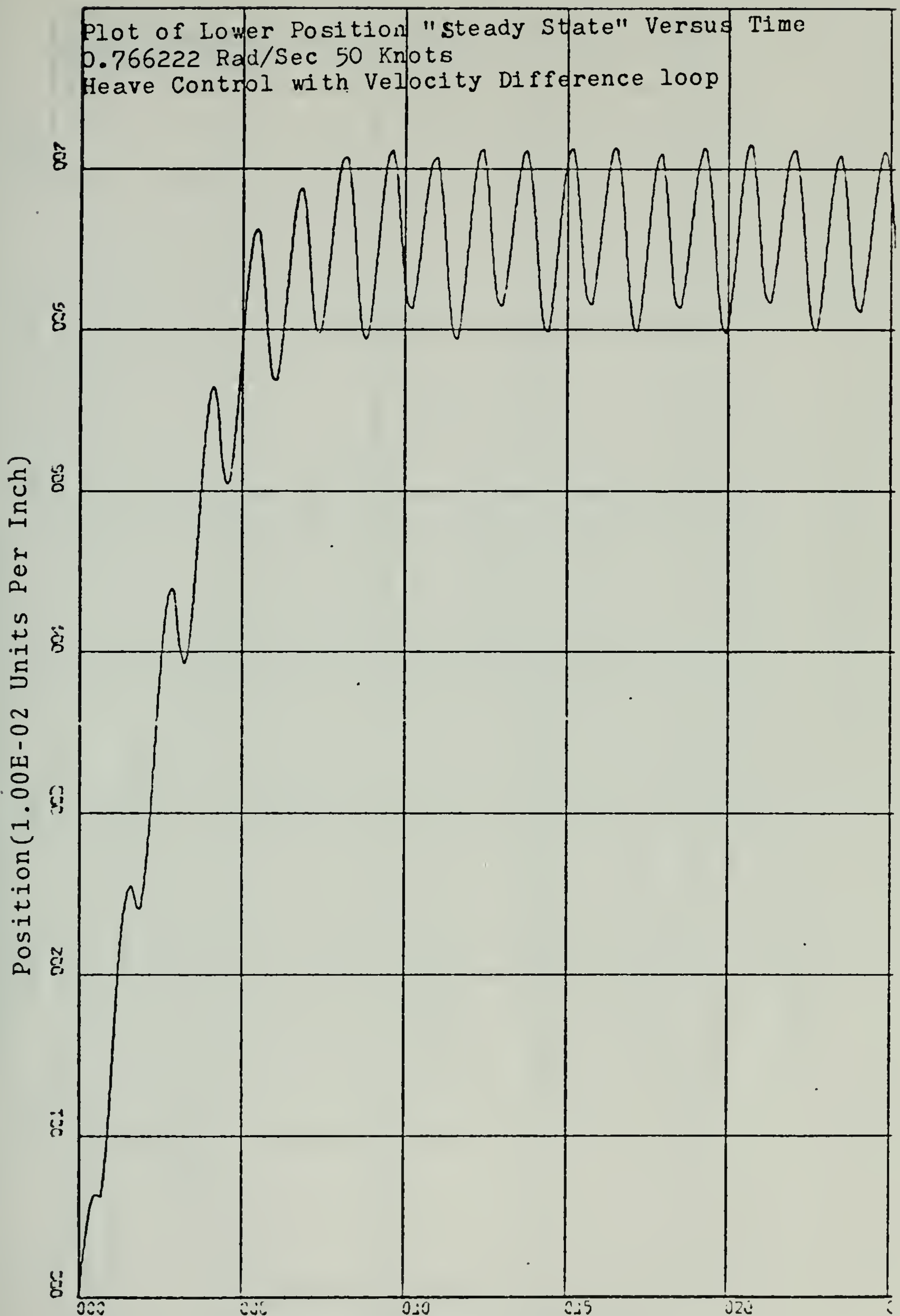

Plot of Lower Position "Steady State" Versus Time
0.766222 Rad/Sec 50 Knots
Heave Control with Velocity Difference loop
Position(1.00E-02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 50

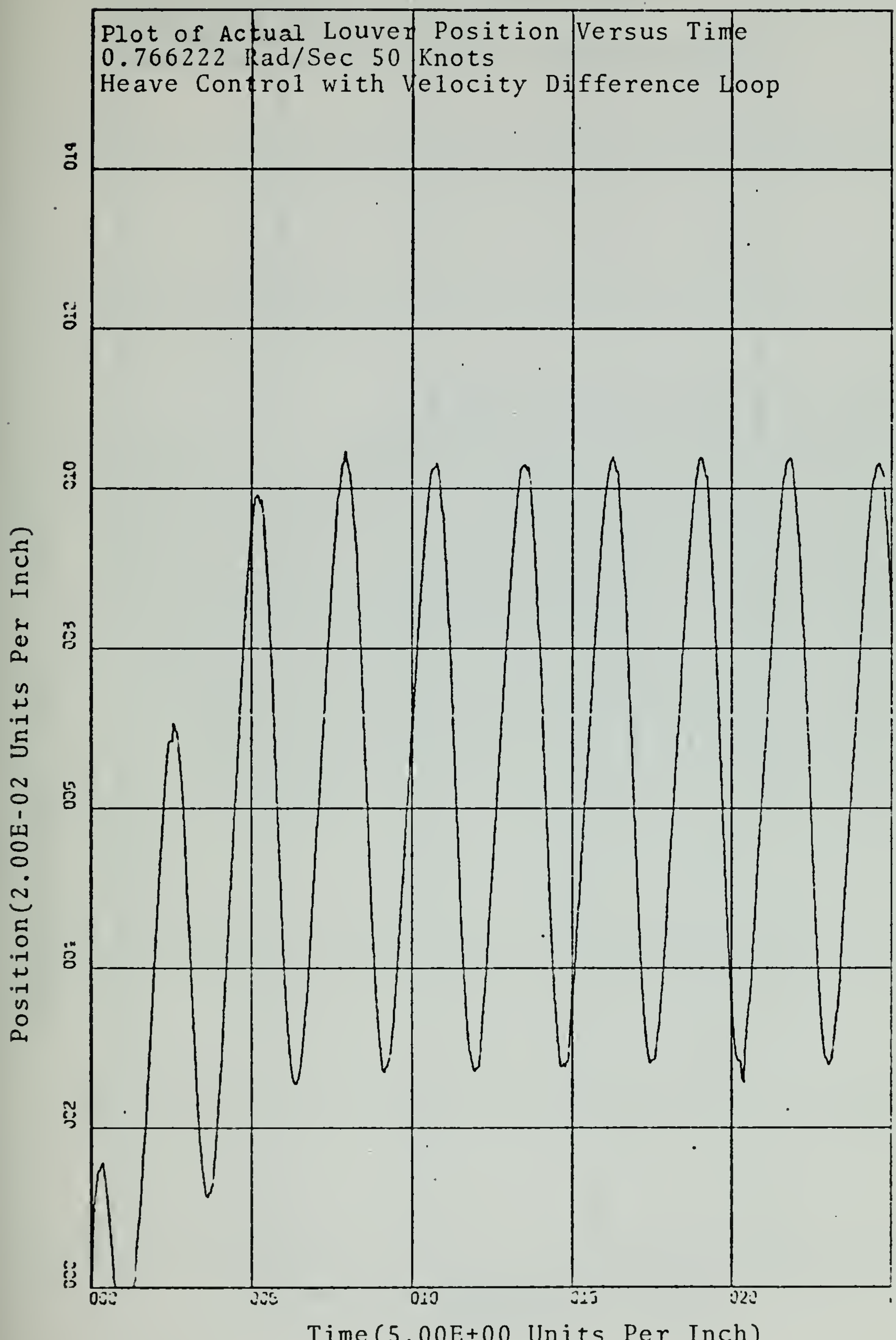

Plot of Actual Louver Position Versus Time
0.766222 Rad/Sec 50 Knots
Heave Control with Velocity Difference Loop
Position(2.00E-02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 51.

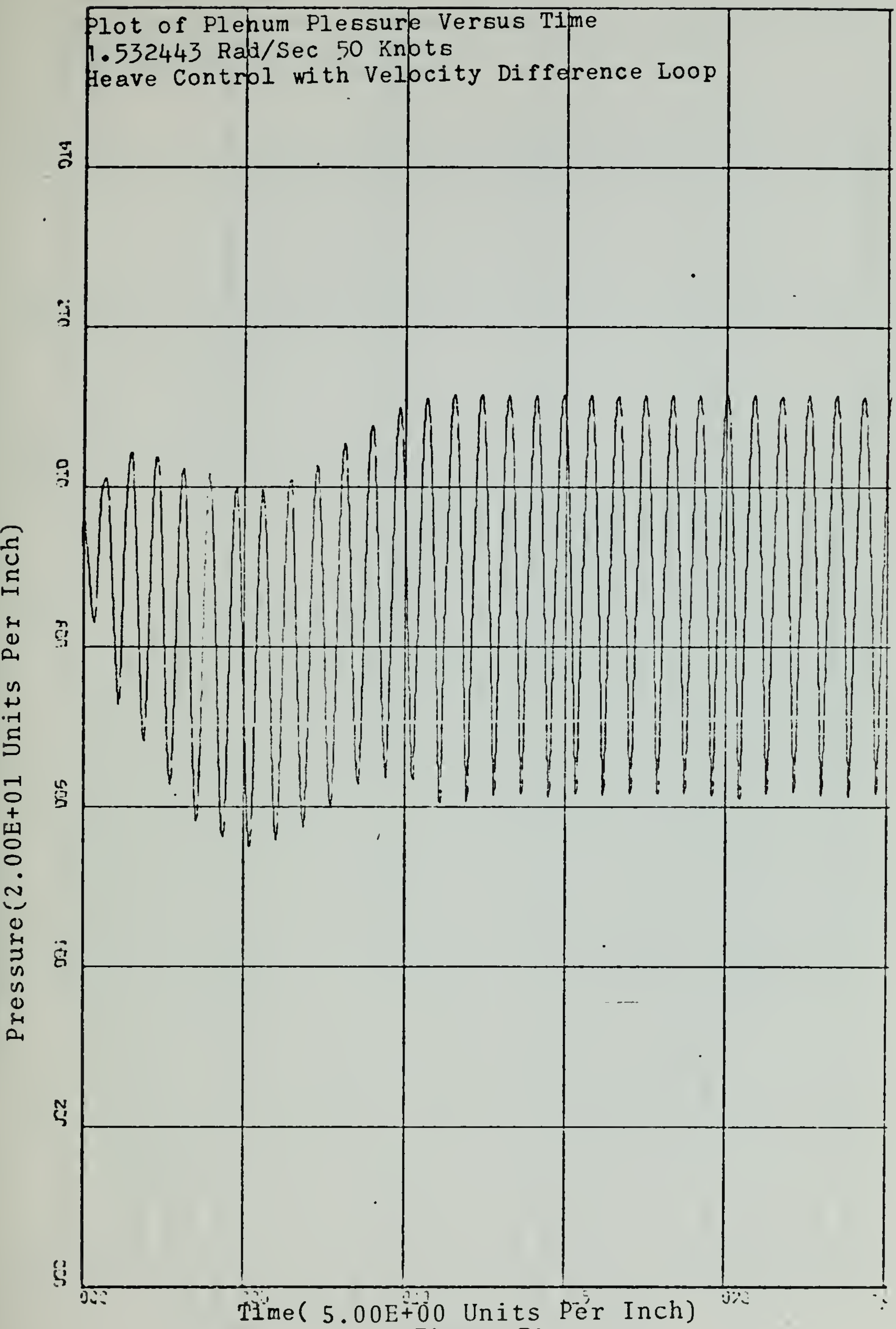
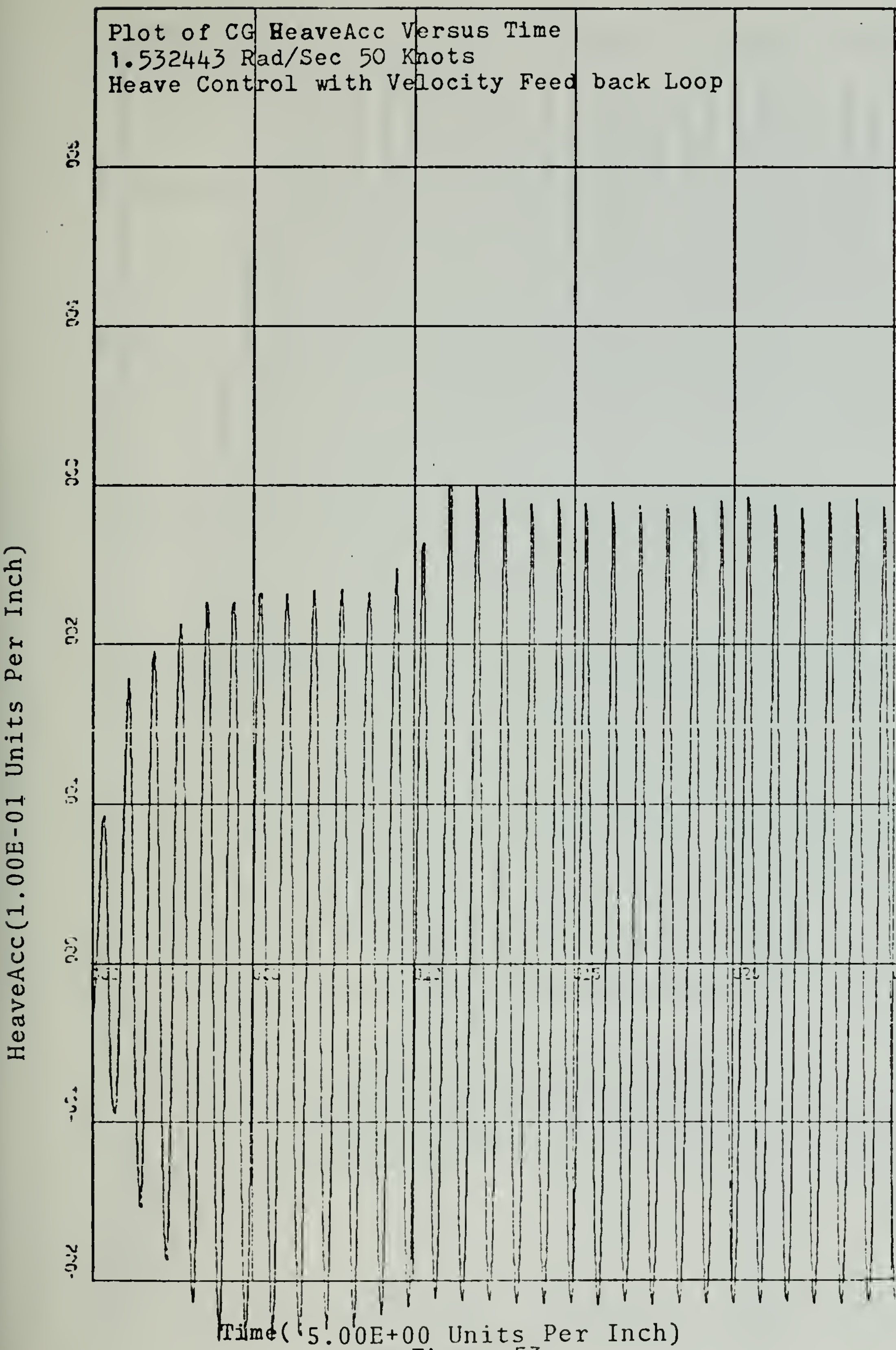

Plot of Plenum Plessure Versus Time
1.532443 Rad/Sec 50 Knots
Heave Control with Velocity Difference Loop
Pressure(2.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 52


Plot of CG HeaveAcc Versus Time
1.532443 Rad/Sec 50 Knots
Heave Control with Velocity Feed back Loop
HeaveAcc(1.00E-01 Units Per Inch)
Time(5.00E+00 Units Per Inch)
Figure 53

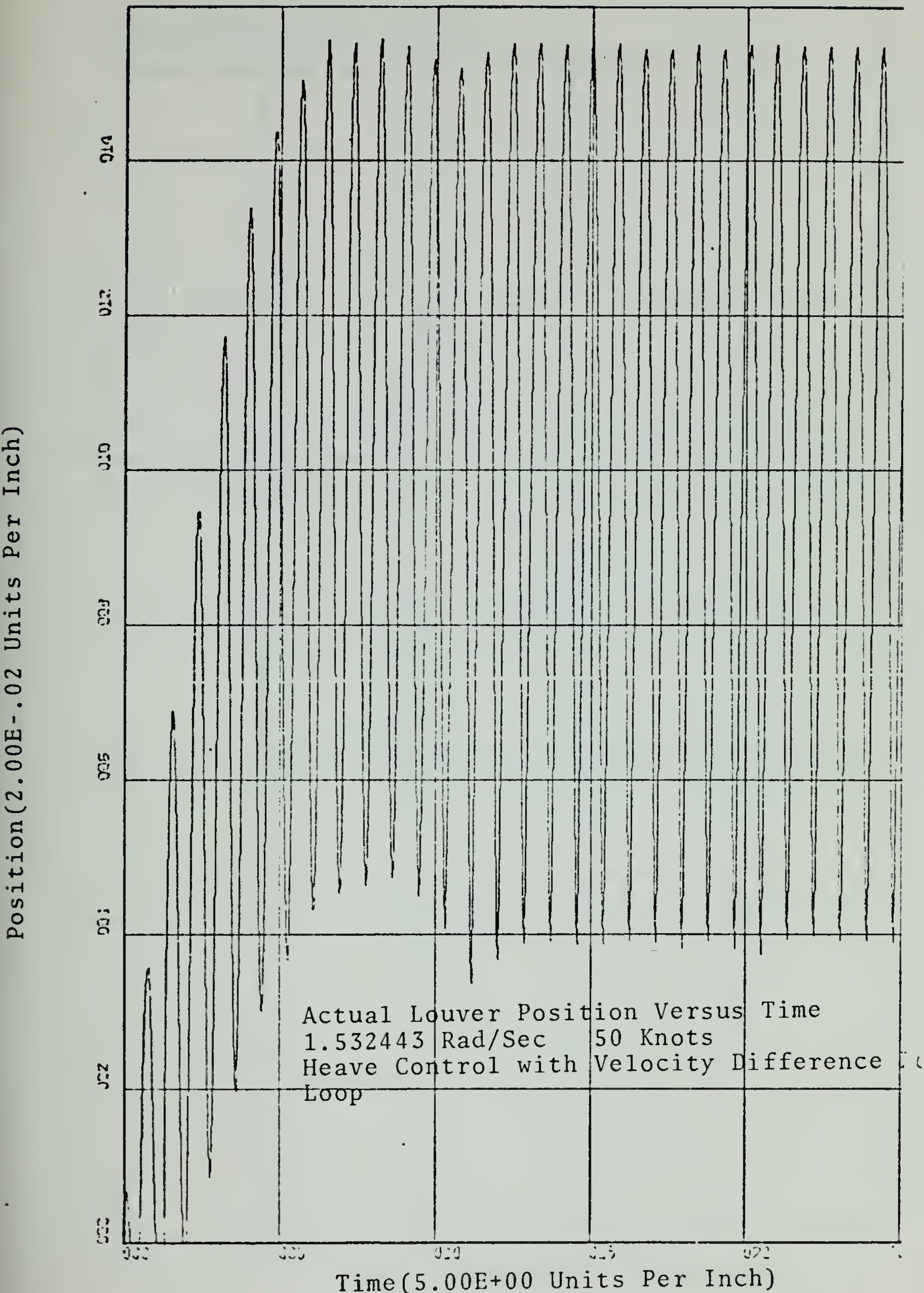

Actual Louver Position Versus Time
1.532443 Rad/Sec 50 Knots
Heave Control with Velocity Difference
Loop
Position(2.00E-.02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 54.

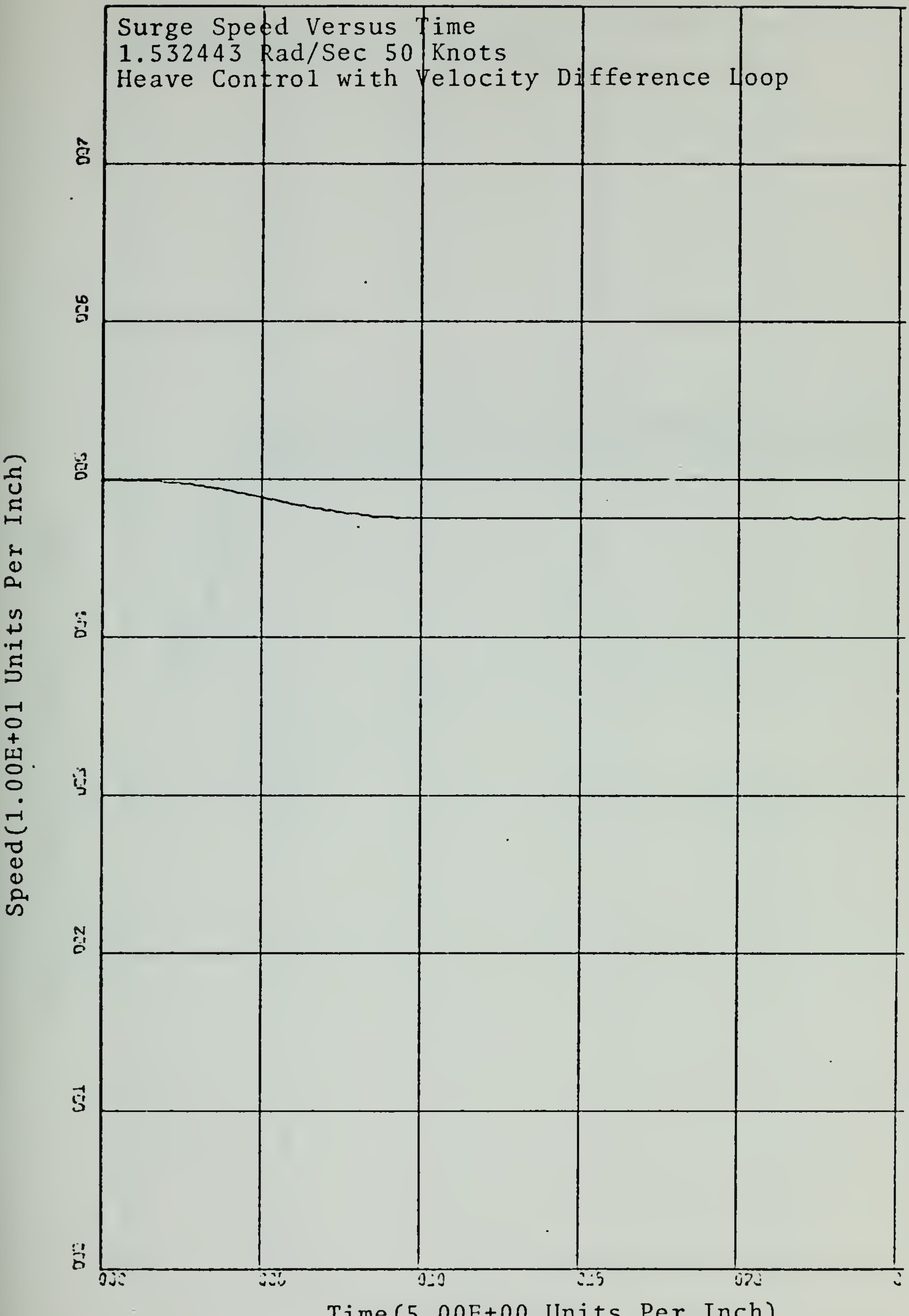

Surge Speed Versus Time
1.532443 Rad/Sec 50 Knots
Heave Control with Velocity Difference Loop
Speed(1.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 55.

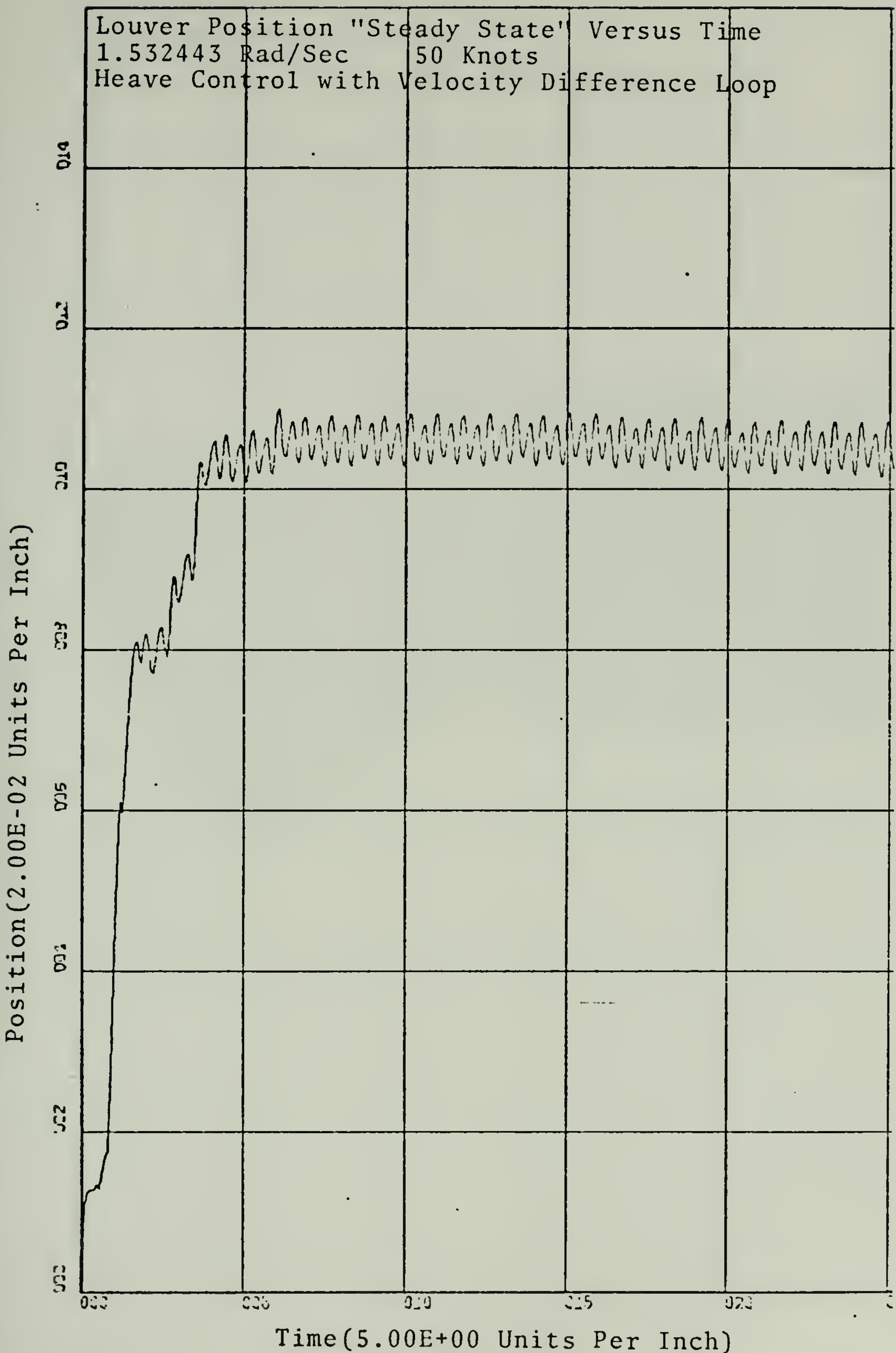
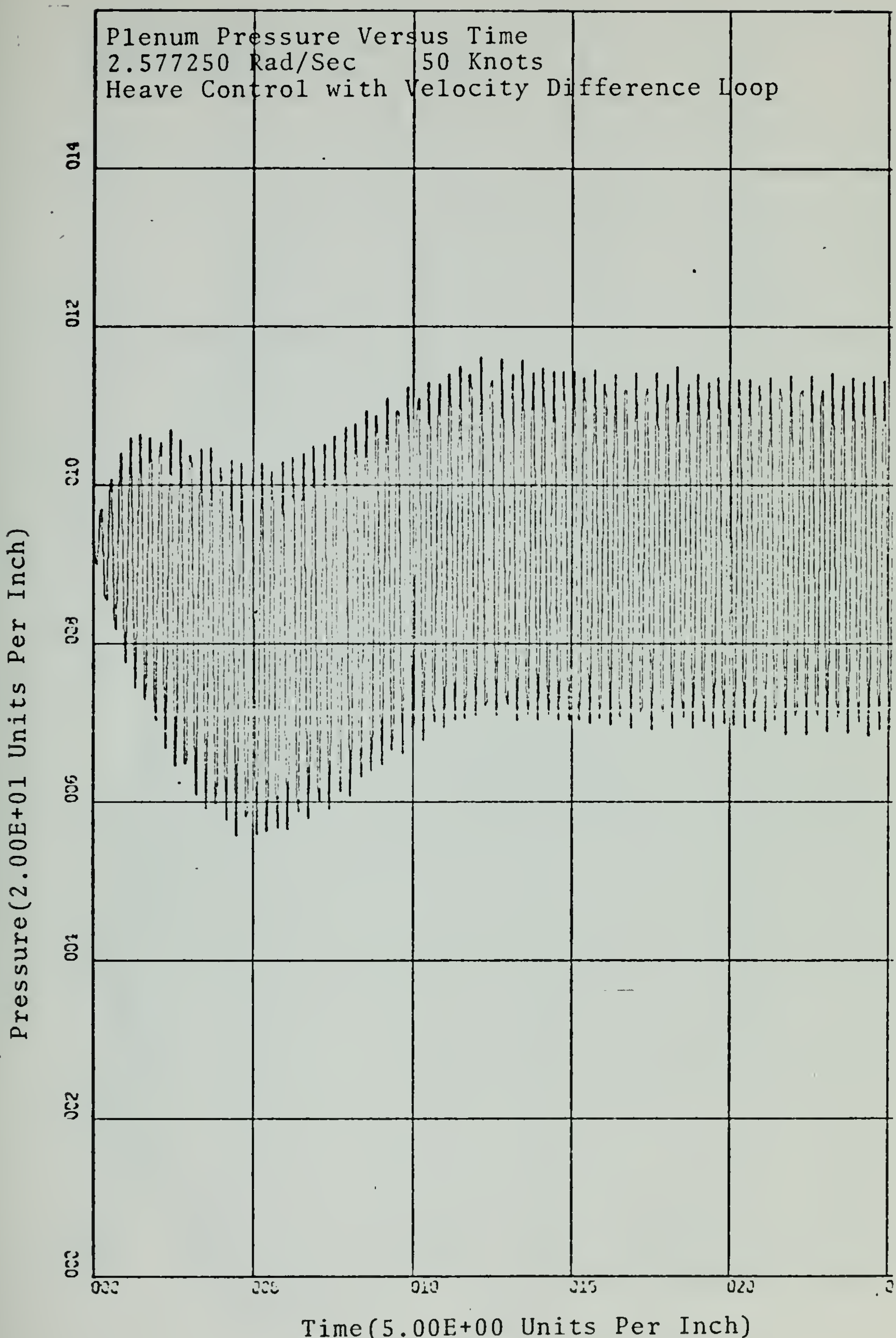

Louver Position "Steady State" Versus Time
1.532443 Rad/Sec 50 Knots
Heave Control with Velocity Difference Loop
Position(2.00E-02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 56.


Plenum Pressure Versus Time
2.577250 Rad/Sec 50 Knots
Heave Control with Velocity Difference Loop
Pressure(2.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)
Figure 57.

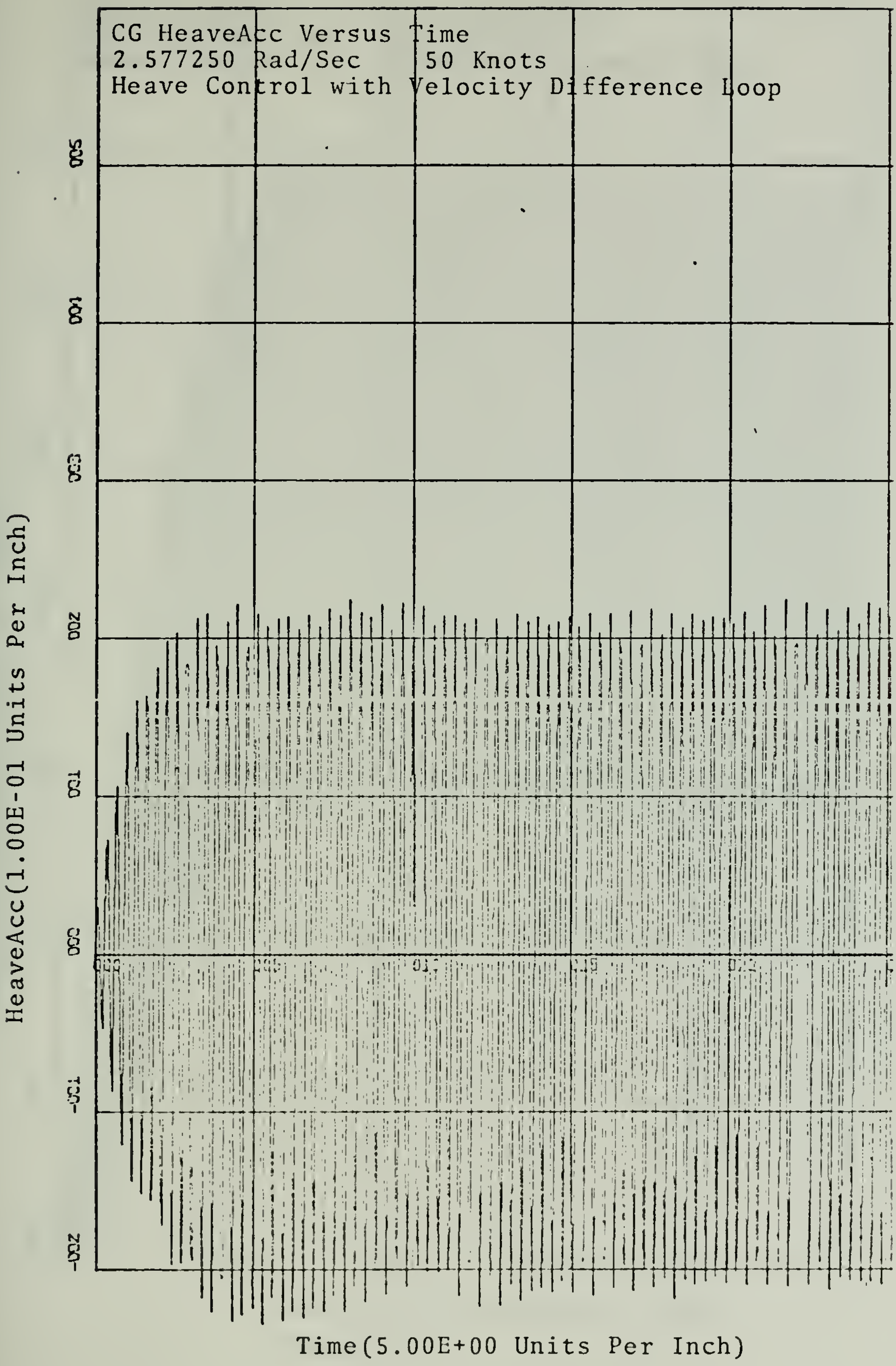

CG HeaveAcc Versus Time
2.577250 Rad/Sec 50 Knots
Heave Control with Velocity Difference Loop
HeaveAcc(1.00E-01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 58.


Actual Louver Position Versus Time
2.577250 Rad/Sec 50 Knots
Heave Control with Velocity Difference Loop
Position(2.00E-02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 59.

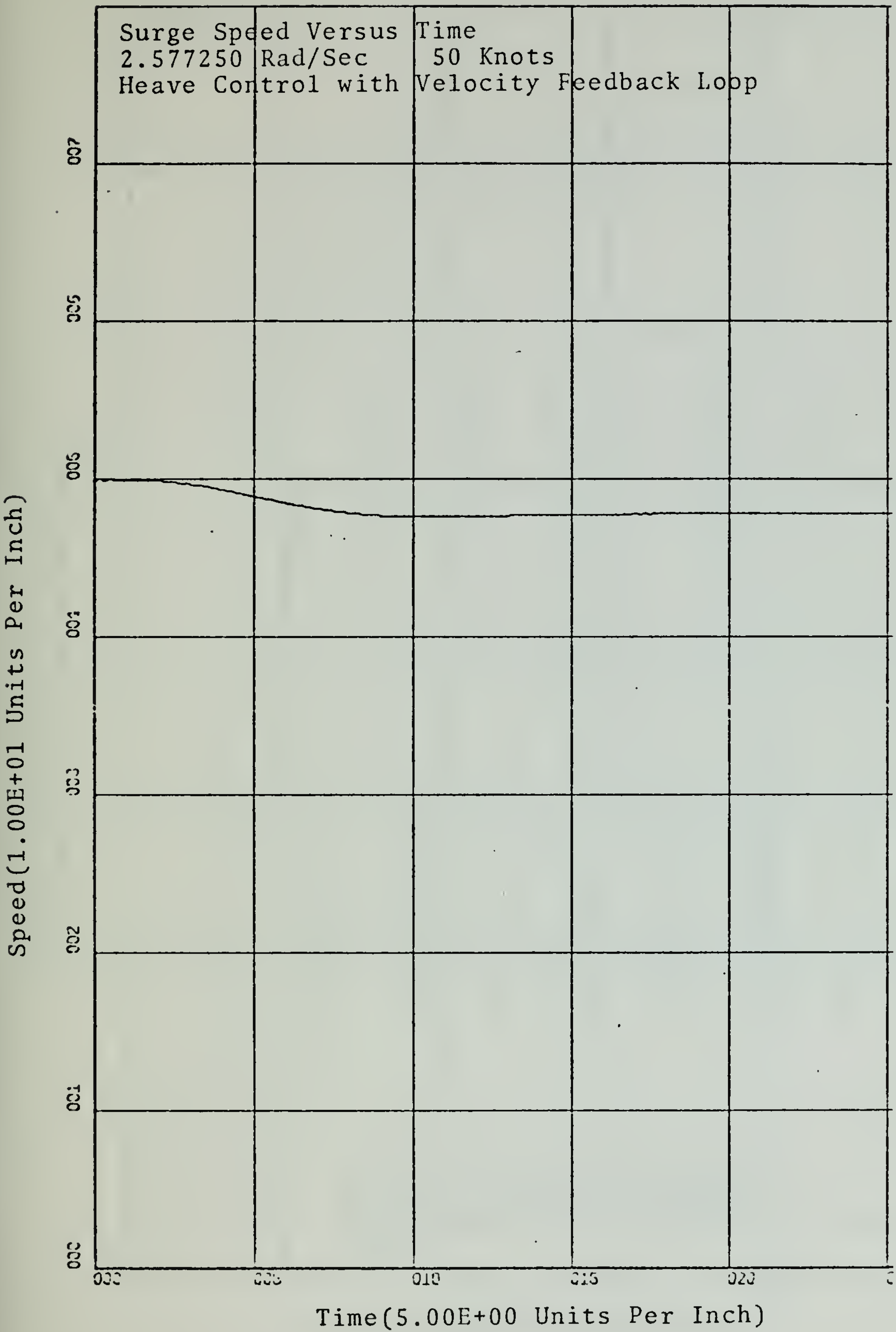

Surge Speed Versus Time
2.577250 Rad/Sec 50 Knots
Heave Control with Velocity Feedback Loop
Speed(1.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 60.

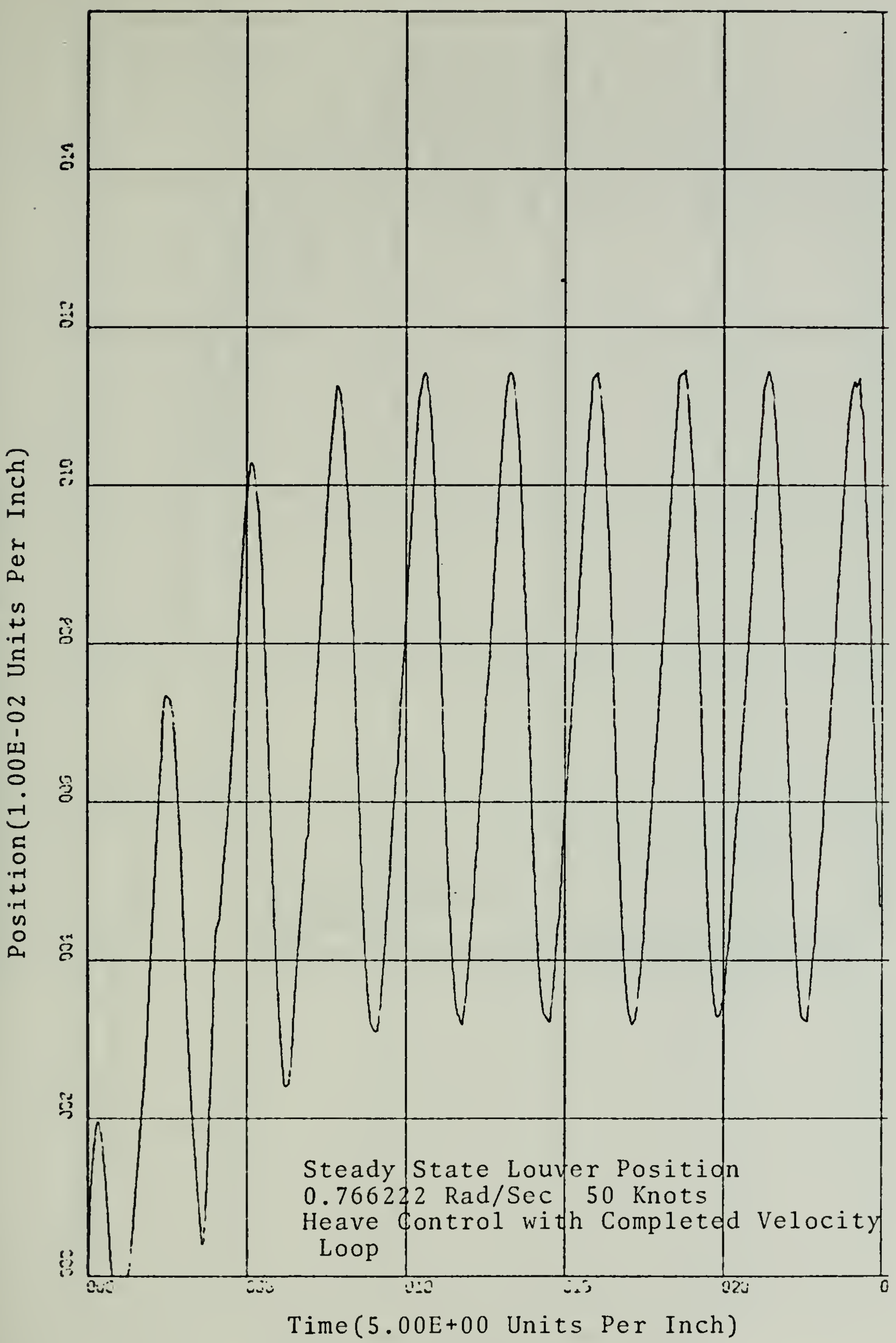

Steady State Louver Position
0.766222 Rad/Sec 50 Knots
Heave Control with Completed Velocity
Loop
Time(5.00E+00 Units Per Inch)
Position(1.00E-02 Units Per Inch)

Figure 61.

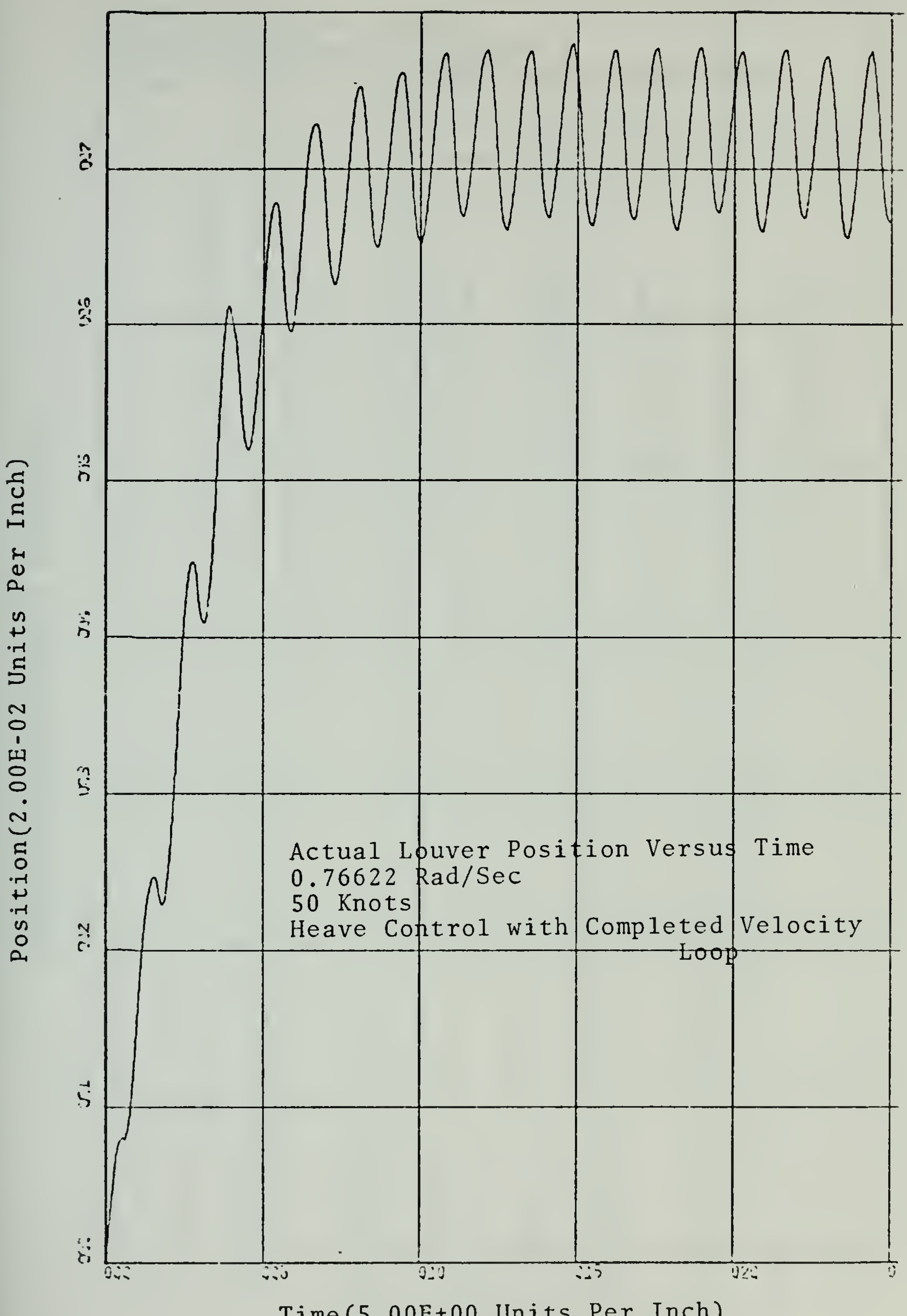

Position(2.00E-02 Units Per Inch)
Actual Louver Position Versus Time
0.76622 Rad/Sec
50 Knots
Heave Control with Completed Velocity Loop
Time(5.00E+00 Units Per Inch)

Figure 62.

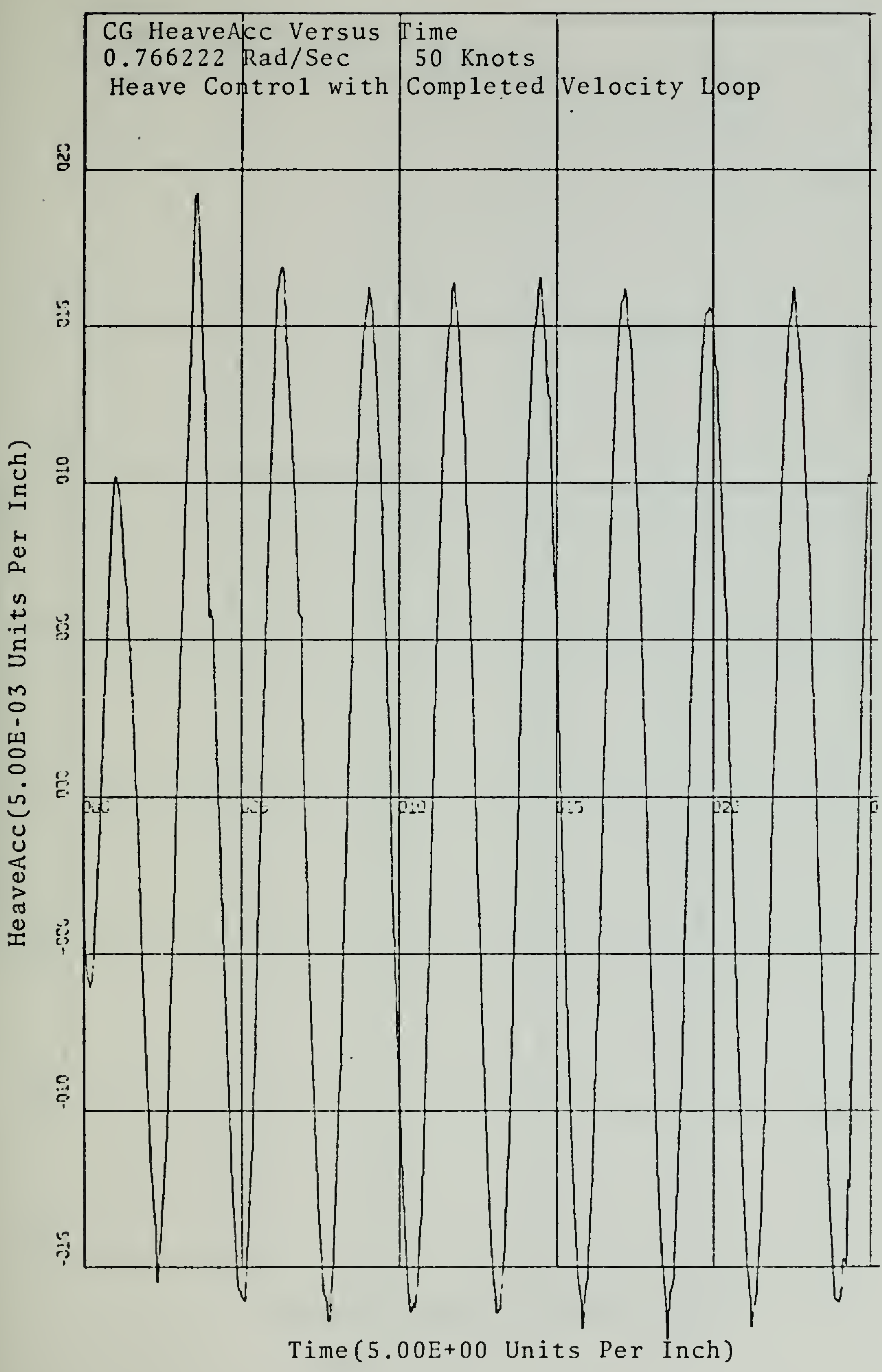

CG HeaveAcc Versus Time
0.766222 Rad/Sec 50 Knots
Heave Control with Completed Velocity Loop
HeaveAcc(5.00E-03 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 63.

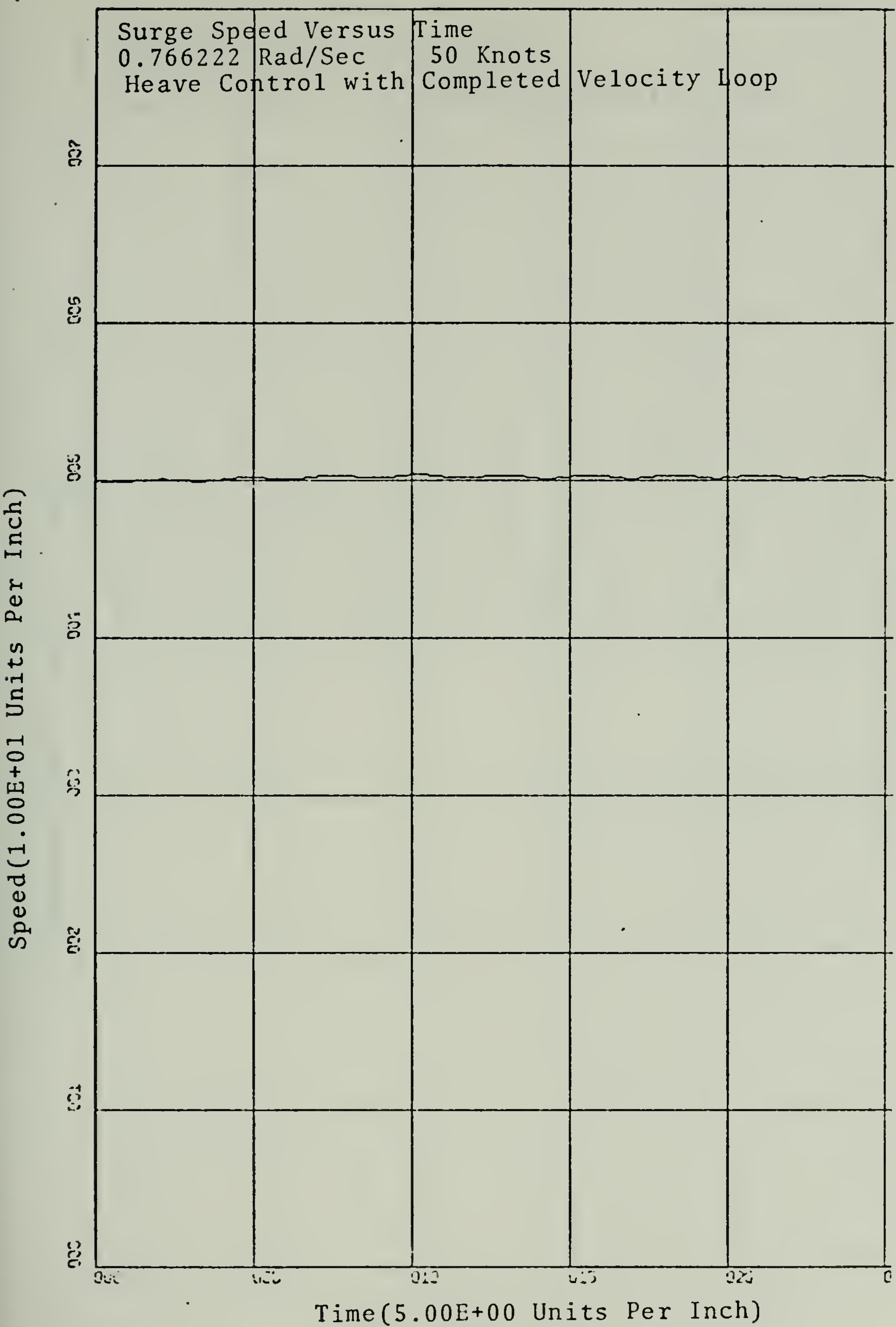
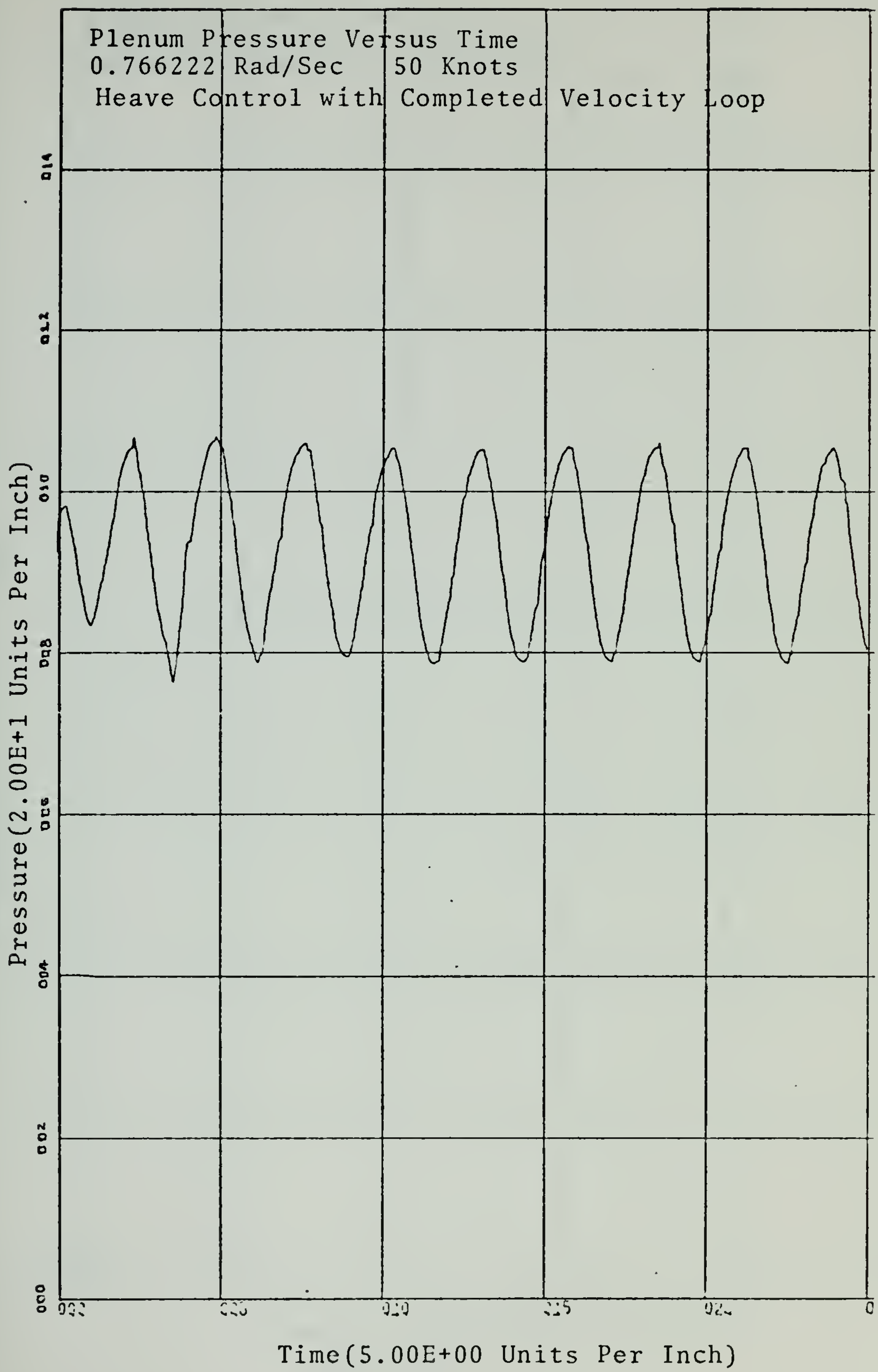

Surge Speed Versus Time
0.766222 Rad/Sec 50 Knots
Heave Control with Completed Velocity Loop
Speed(1.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 64.



Plenum Pressure Versus Time
0.766222 Rad/Sec 50 Knots
Heave Control with Completed Velocity Loop
Pressure(2.00E+1 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 65.

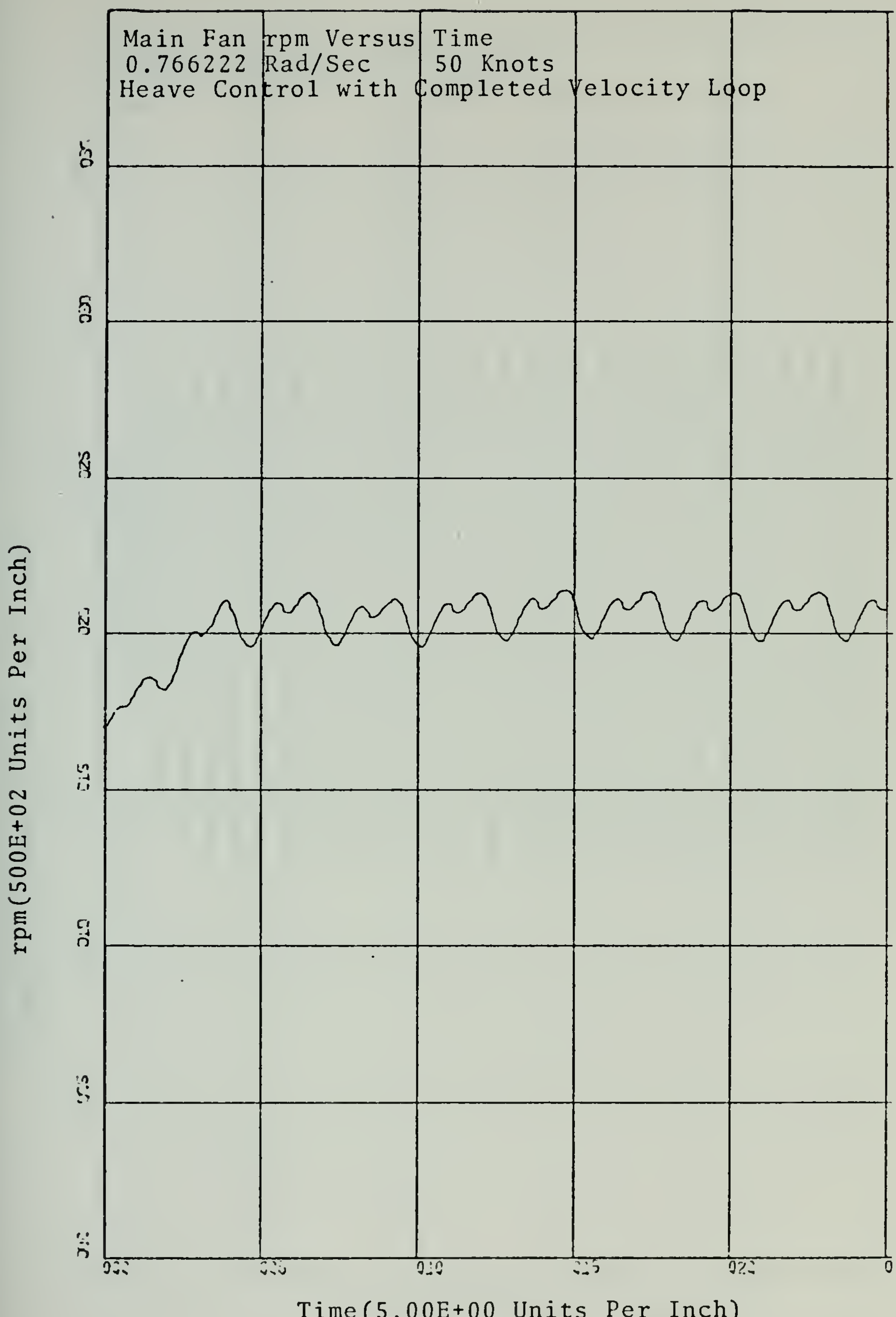

Main Fan rpm Versus Time
0.766222 Rad/Sec 50 Knots
Heave Control with Completed Velocity Loop
rpm(500E+02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 66.

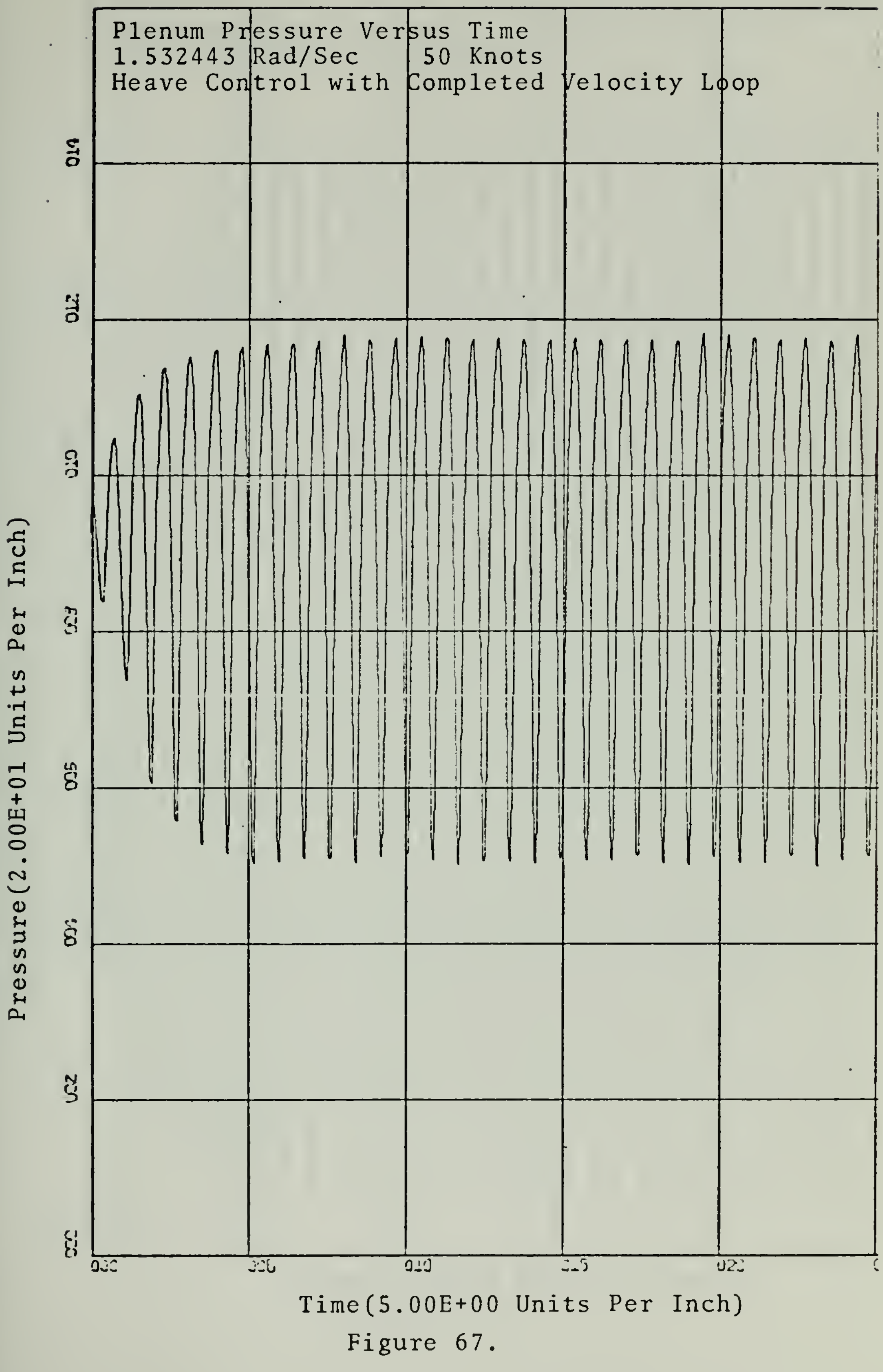
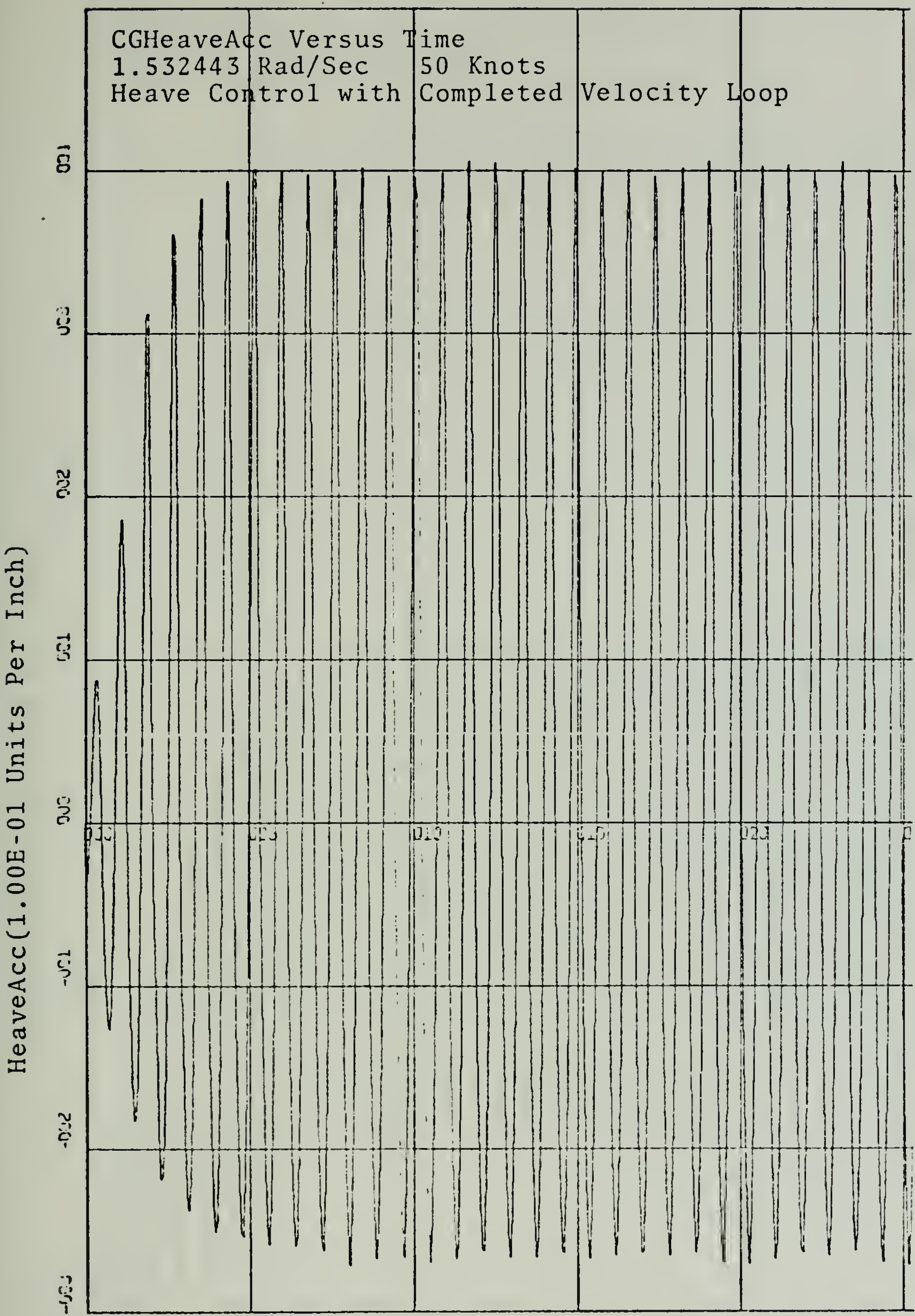

Plenum Pressure Versus Time
1.532443 Rad/Sec 50 Knots
Heave Control with Completed Velocity Loop
Pressure(2.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 67.



Time(5.00E+00 Units Per Inch)

Figure 68.

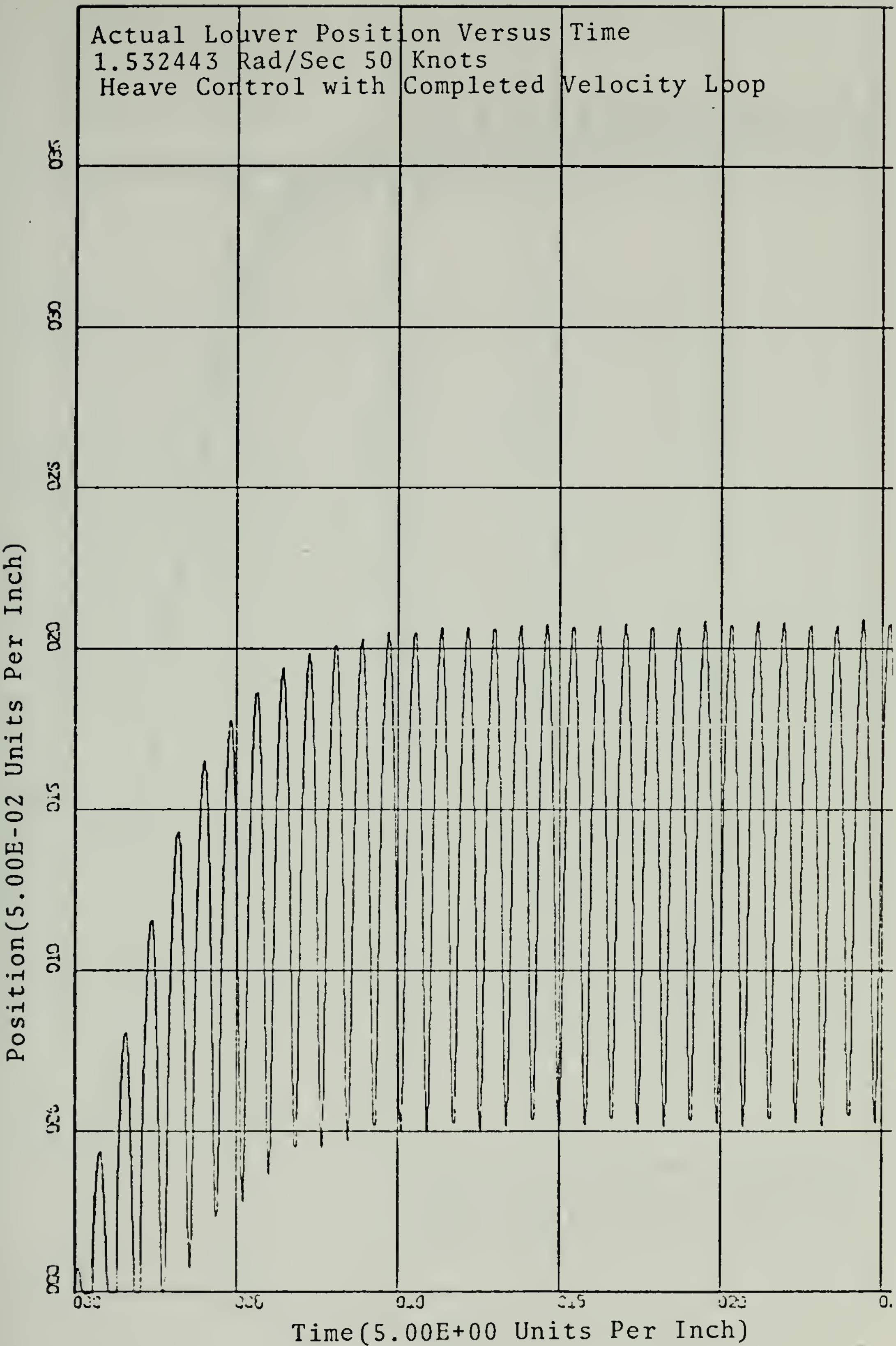

Actual Louver Position Versus Time
1.532443 Rad/Sec 50 Knots
Heave Control with Completed Velocity Loop
Position(5.00E-02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 69.

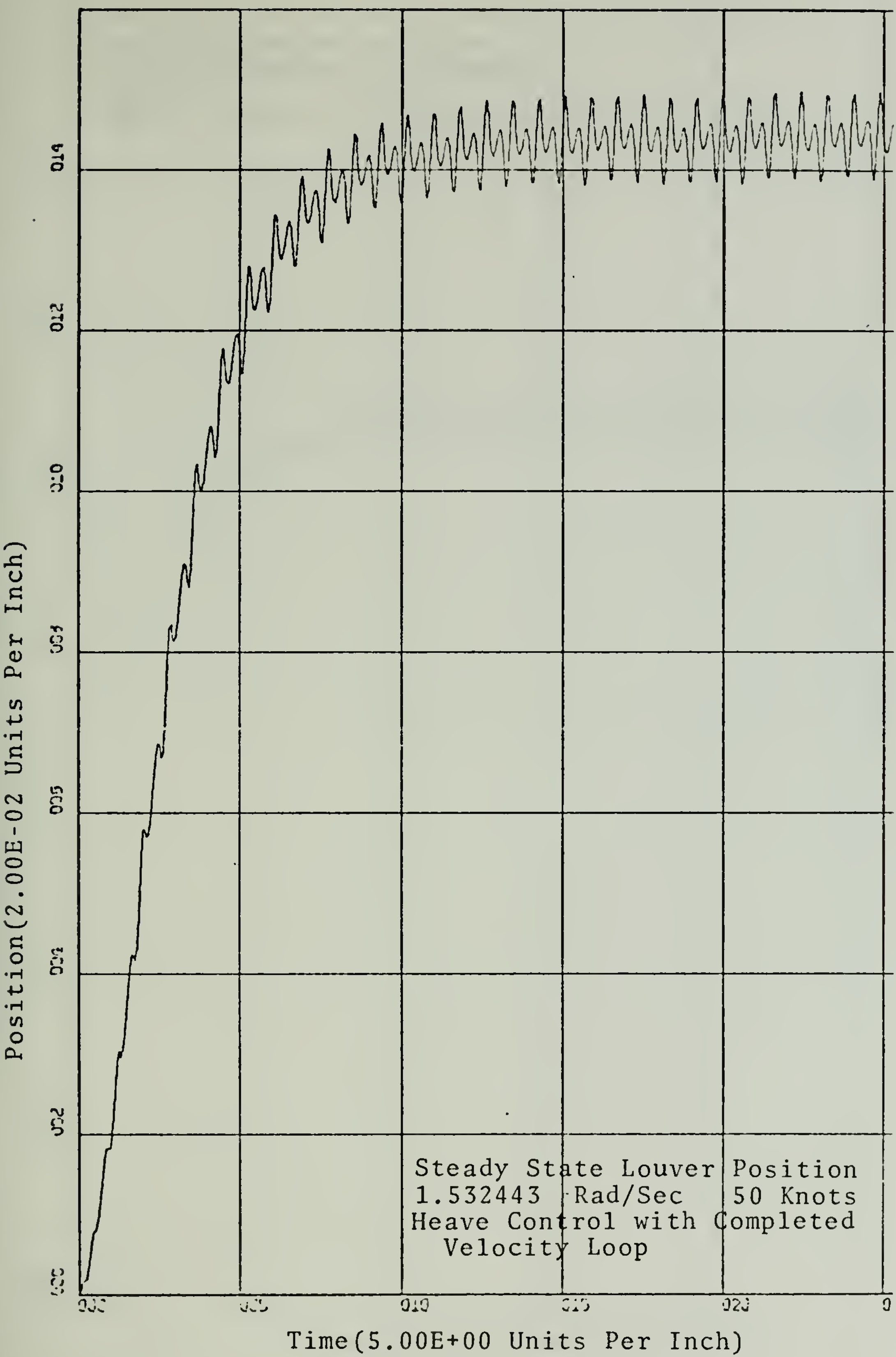

Position(2.00E-02 Units Per Inch)
Steady State Louver Position
1.532443 Rad/Sec 50 Knots
Heave Control with Completed
Velocity Loop
Time(5.00E+00 Units Per Inch)

Figure 70.

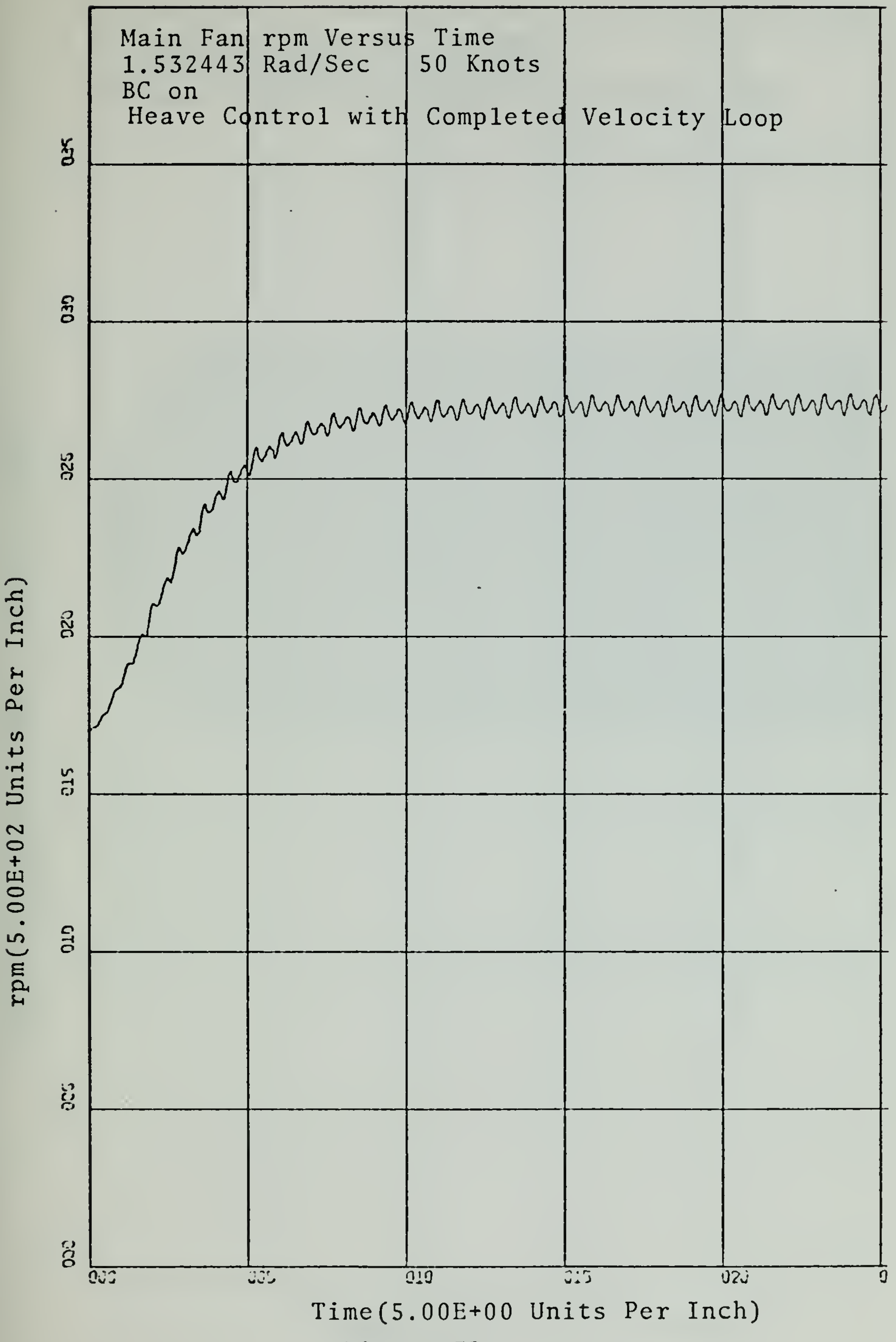

Main Fan rpm Versus Time
1.532443 Rad/Sec 50 Knots
BC on
Heave Control with Completed Velocity Loop
rpm(5.00E+02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 71.

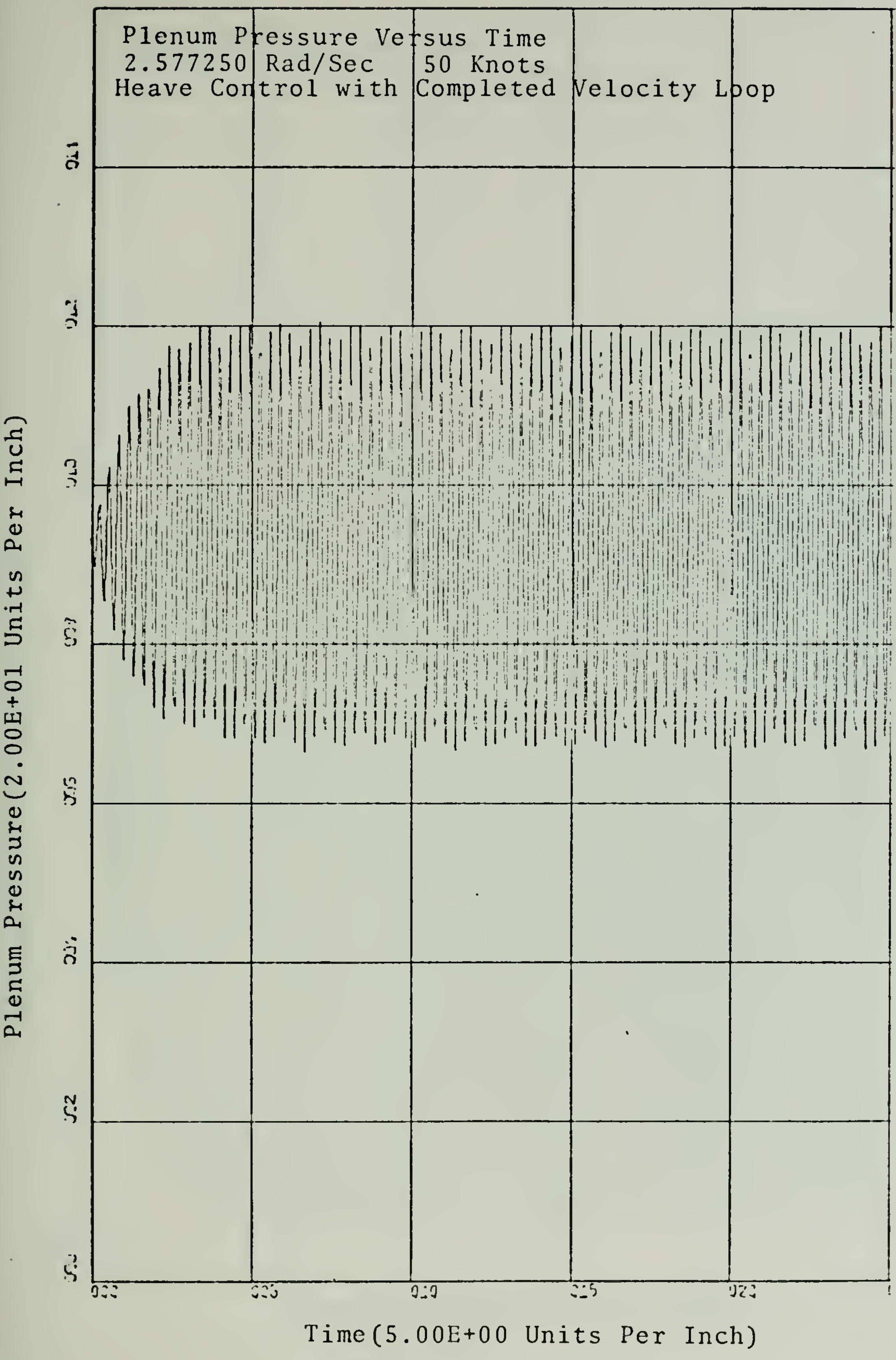

Plenum Pressure Versus Time
2.577250 Rad/Sec 50 Knots
Heave Control with Completed Velocity Loop
Plenum Pressure(2.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 72.

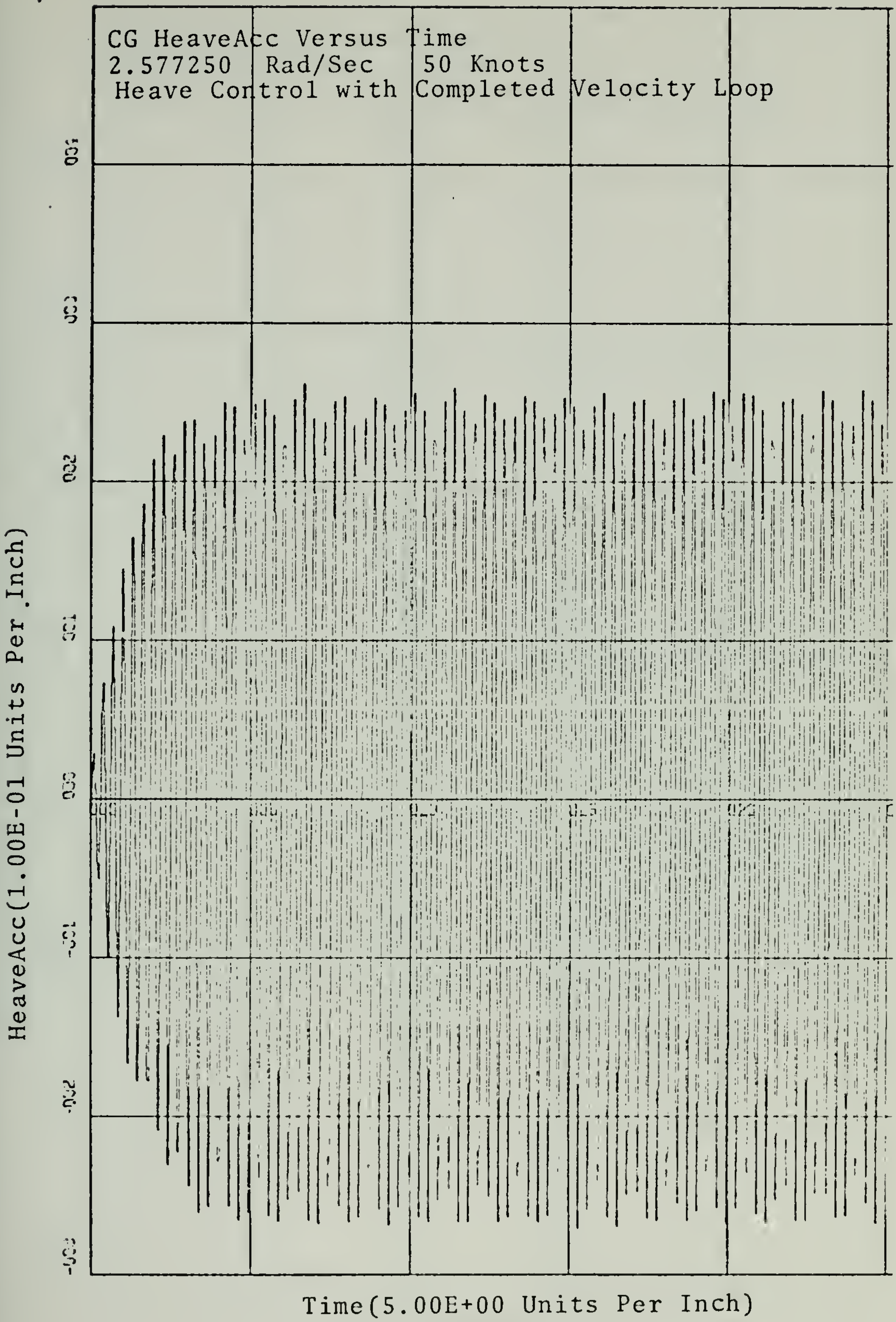

CG HeaveAcc Versus Time
2.577250 Rad/Sec 50 Knots
Heave Control with Completed Velocity Loop
HeaveAcc(1.00E-01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 73.

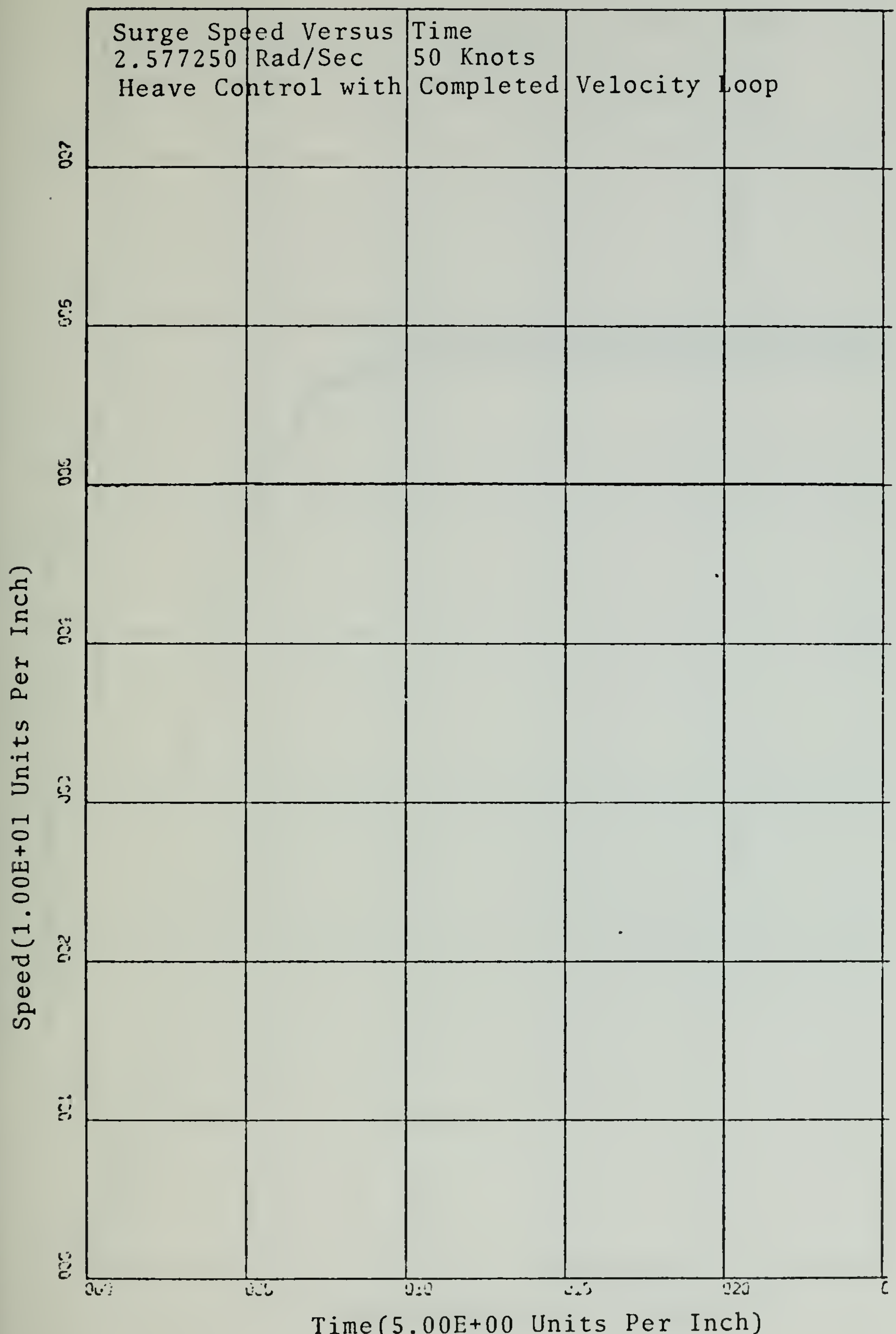

Surge Speed Versus Time
2.577250 Rad/Sec 50 Knots
Heave Control with Completed Velocity Loop
Speed(1.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 74.

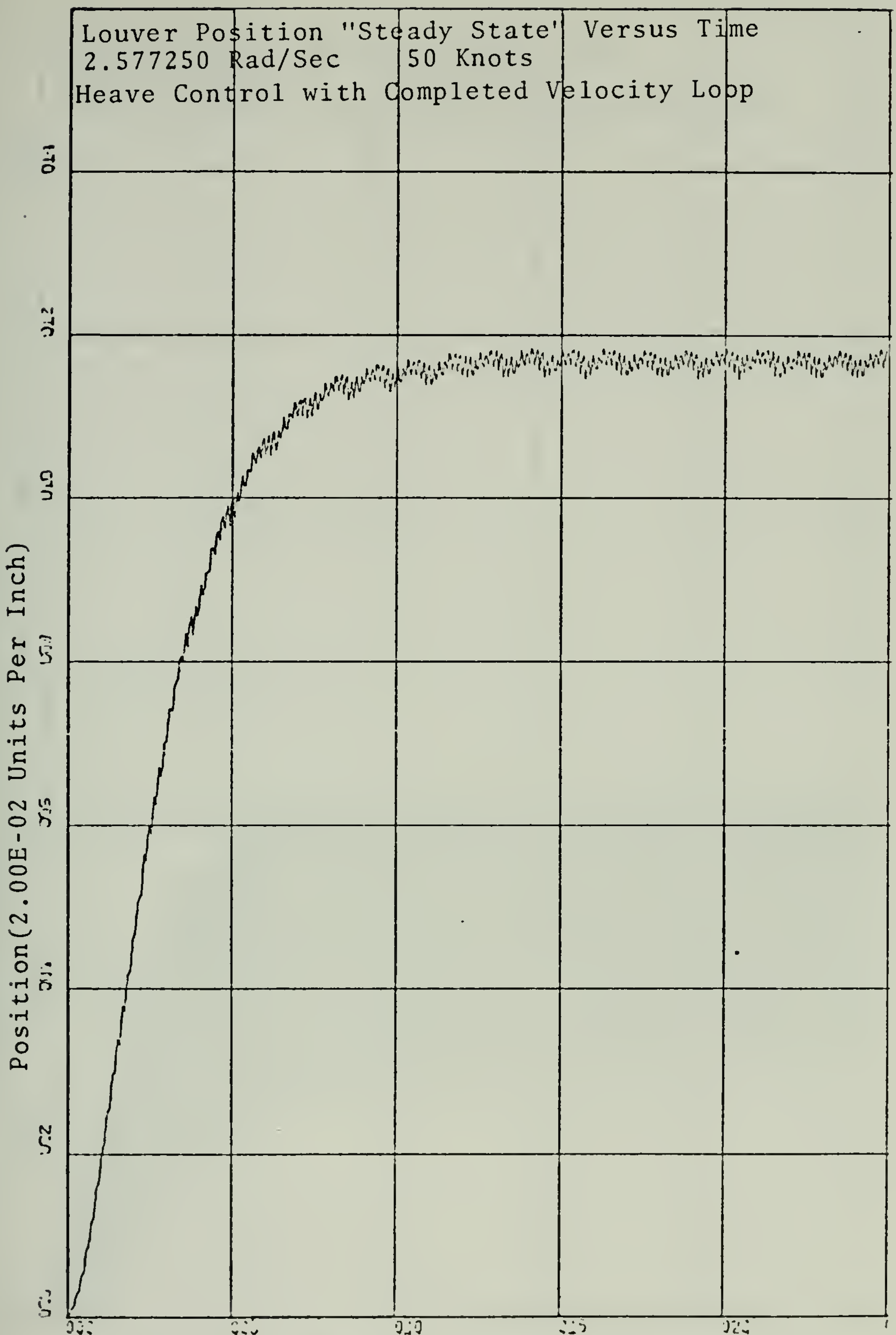
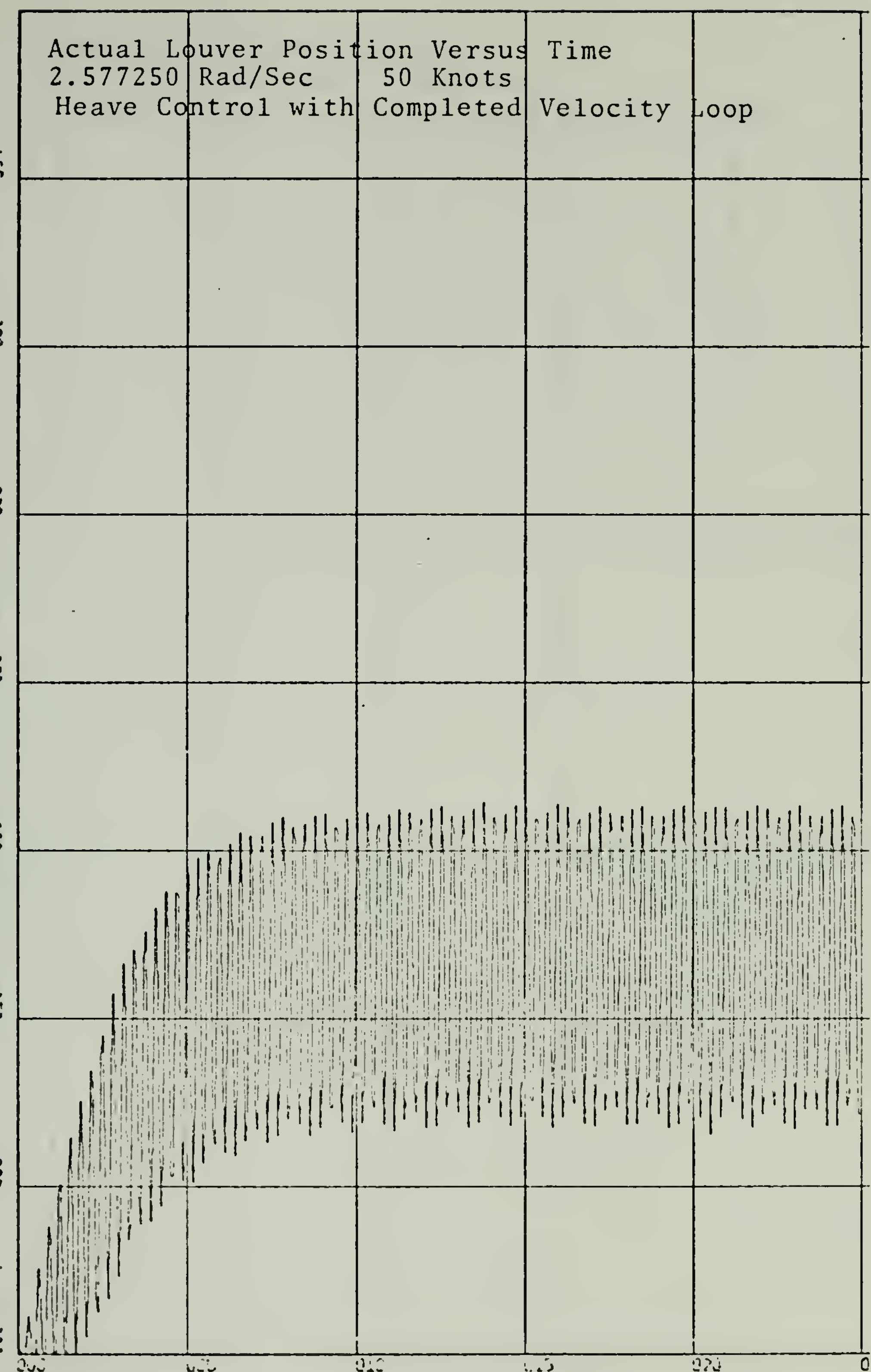

Louver Position "Steady State" Versus Time
2.577250 Rad/Sec 50 Knots
Heave Control with Completed Velocity Loop
Position(2.00E-02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 75.



Position(5.00E-02 Units Per Inch)

Time(5.00E+00 Units Per Inch)

Figure 76.

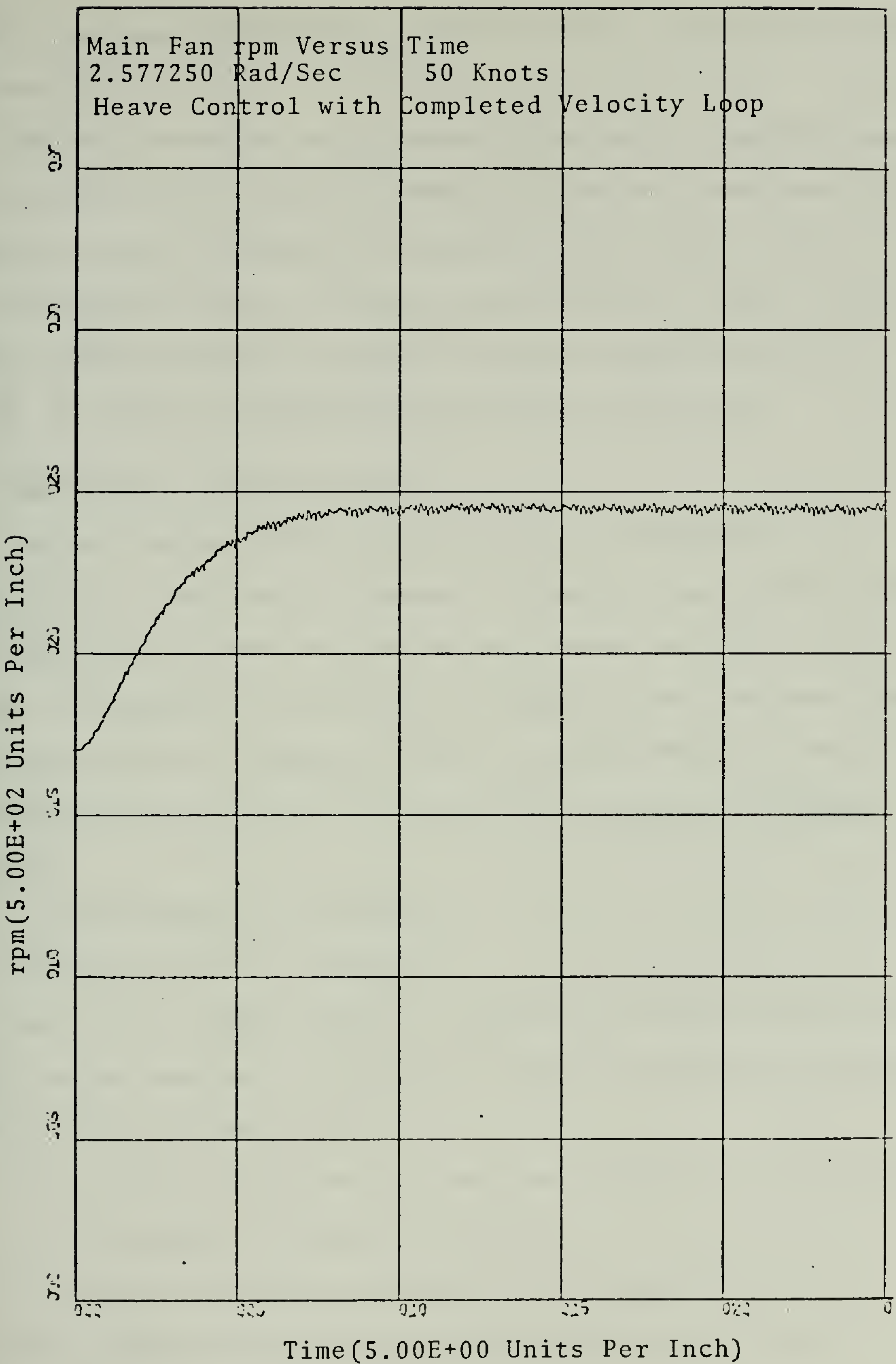

Main Fan rpm Versus Time
2.577250 Rad/Sec 50 Knots
Heave Control with Completed Velocity Loop
rpm(5.00E+02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 77.

even shows some improvement over the craft's parameters with no controls.

Before proceeding with computer runs with irregular seas, it should be noted that all runs included here were made with a louver size of sixteen by nine feet, with what is felt to be acceptable results. Several runs made with larger louver sizes showed further increases in heave acceleration but with, of course, accompanying increases in fan rpm.

B. BEHAVIOR IN IRREGULAR SEAS

Actual design of the heave/velocity controller was accomplished using single frequency sinusoidal waves; here data is presented to show the system under more realistic conditions. Simulation studies with irregular seas consumes three to four times the computer time for single frequency runs, therefore the study was restricted to two cases at moderate speeds.

1. Sea State 3 - 50 knots
2. Sea State 4 - 40 knots

As in the single frequency studies, both wave conditions will be met head on, creating the most severe heave parameters for each set of conditions.

Four series of graphs for each sea state will be presented.

1. No control, Figures 78 to 83.
2. Velocity difference loop only, Figures 84 to 91.
3. Heave control with the velocity difference loop, Figures 92 to 103.

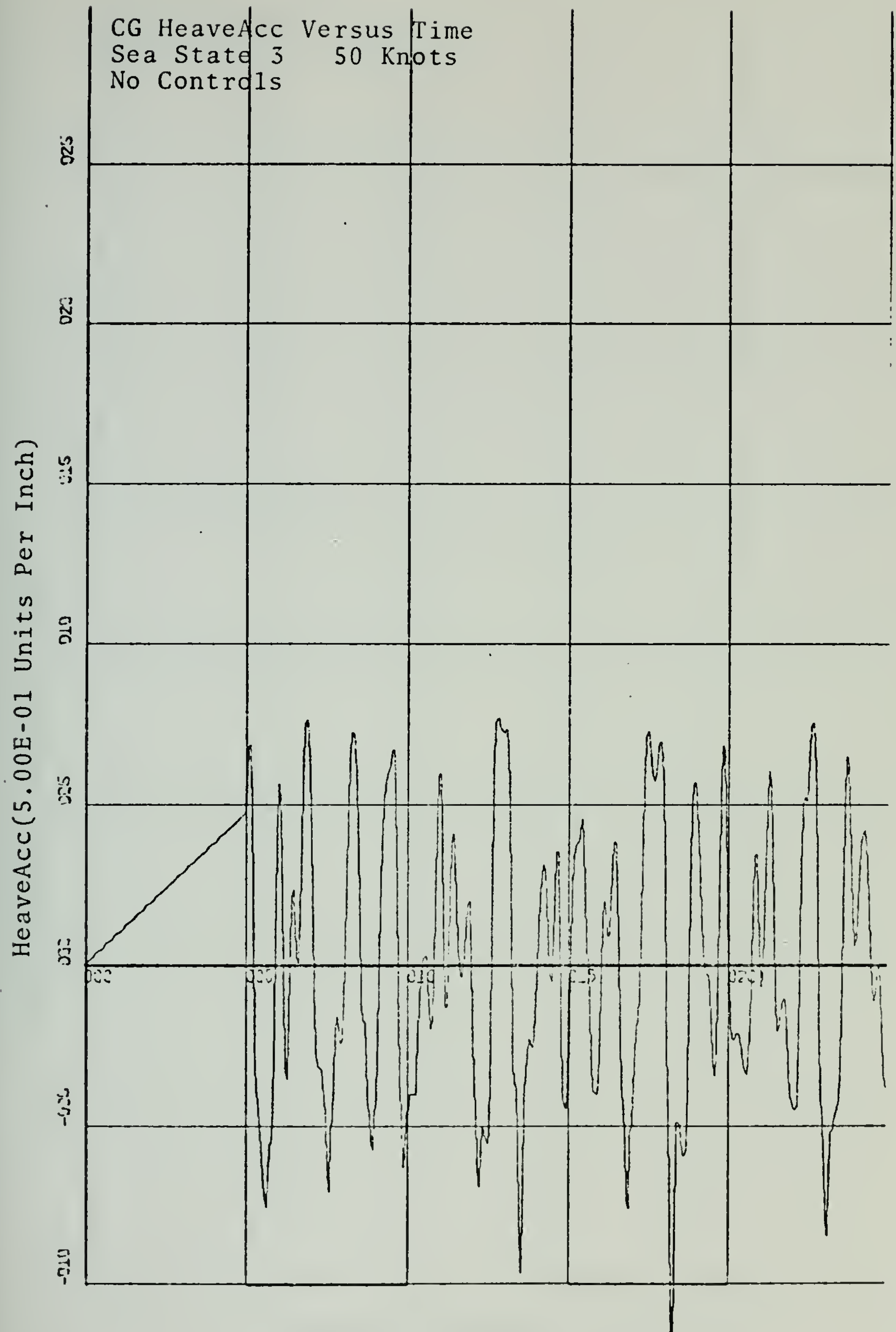

CG HeaveAcc Versus Time
Sea State 3 50 Knots
No Controls
HeaveAcc(5.00E-01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 78.

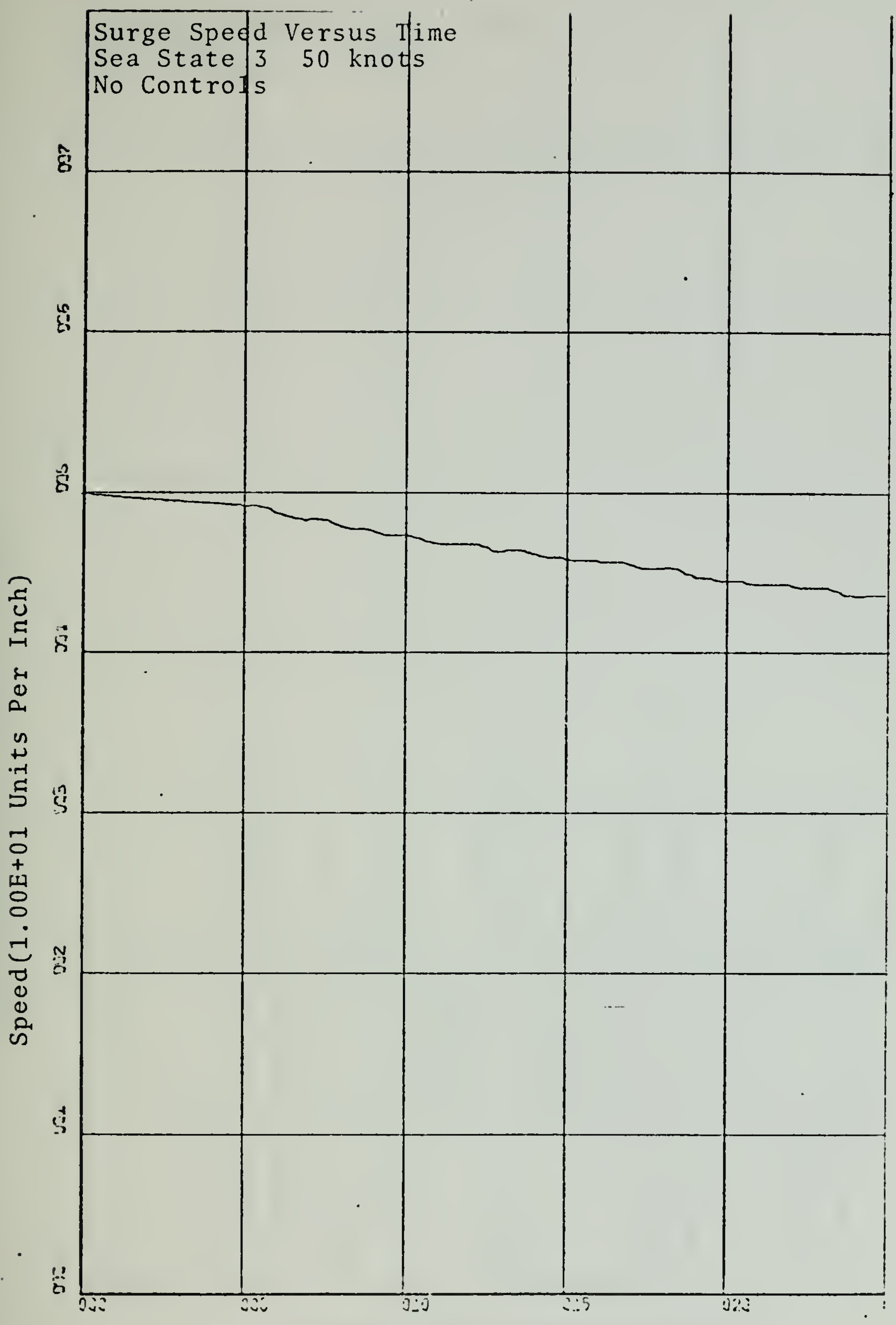

Surge Speed Versus Time
Sea State 3 50 knots
No Controls
Speed(1.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 79.

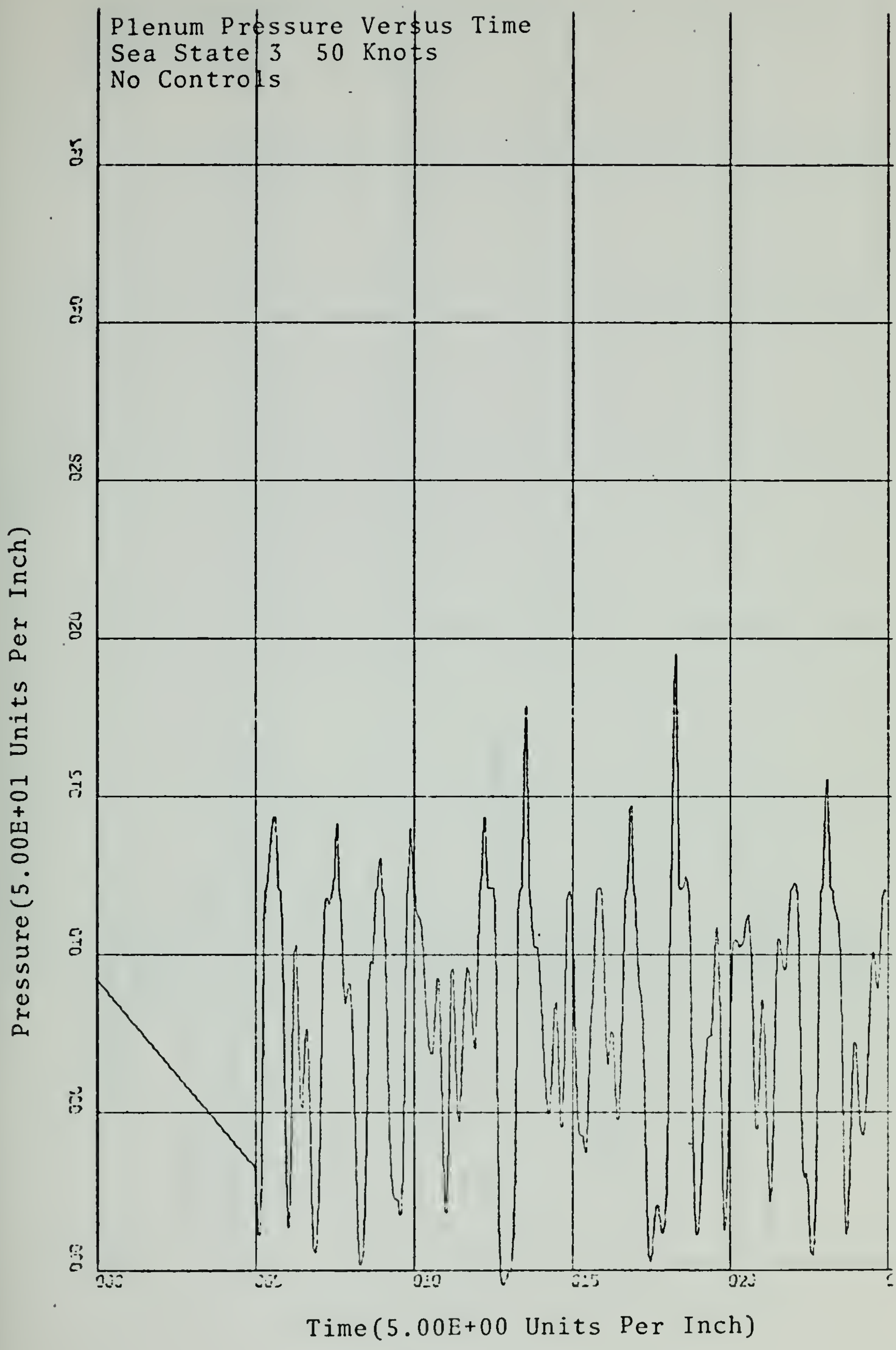

Plenum Pressure Versus Time
Sea State 3 50 Knots
No Controls
Pressure(5.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 80.

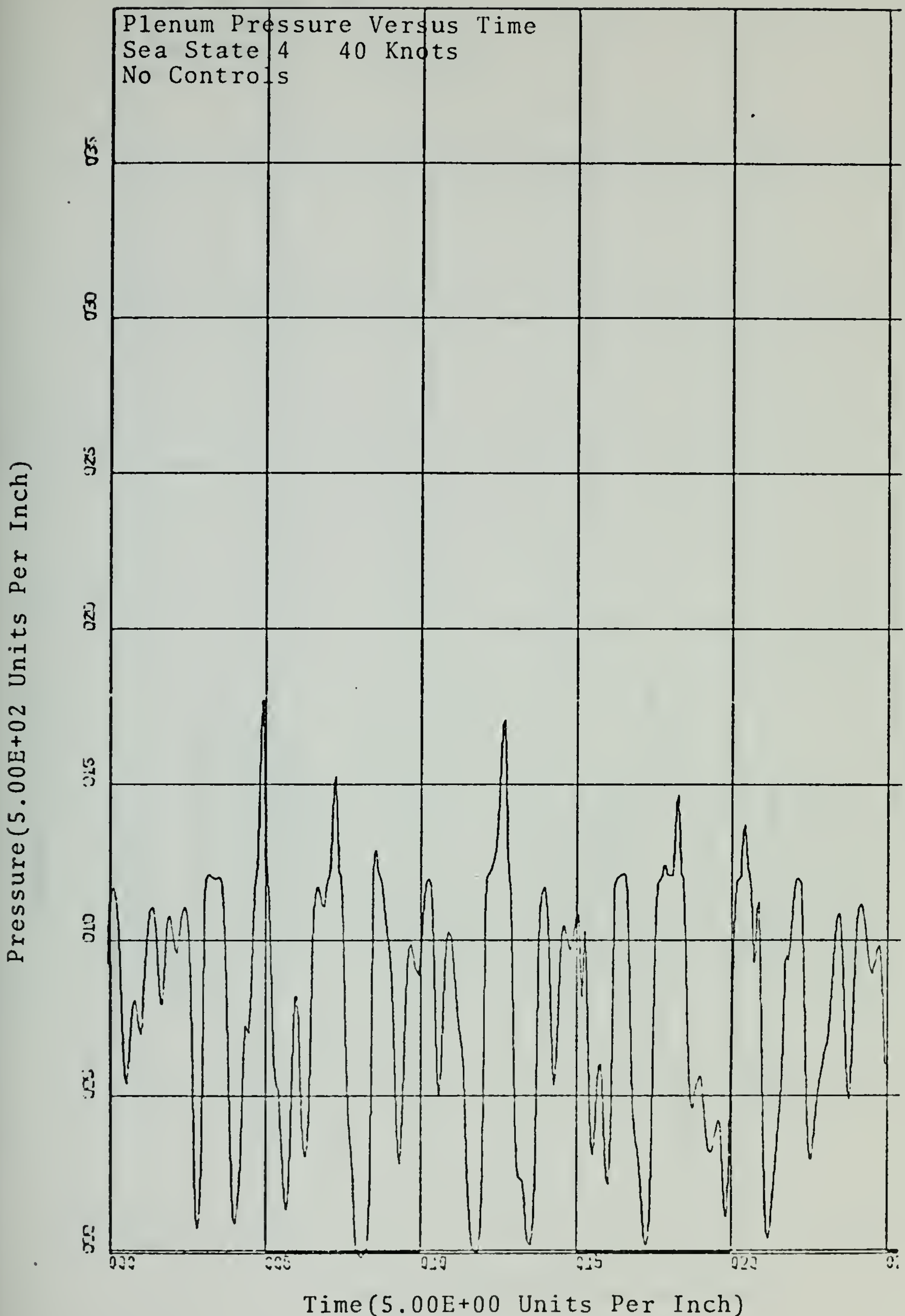

Plenum Pressure Versus Time
Sea State 4 40 Knots
No Controls
Pressure(5.00E+02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 81.

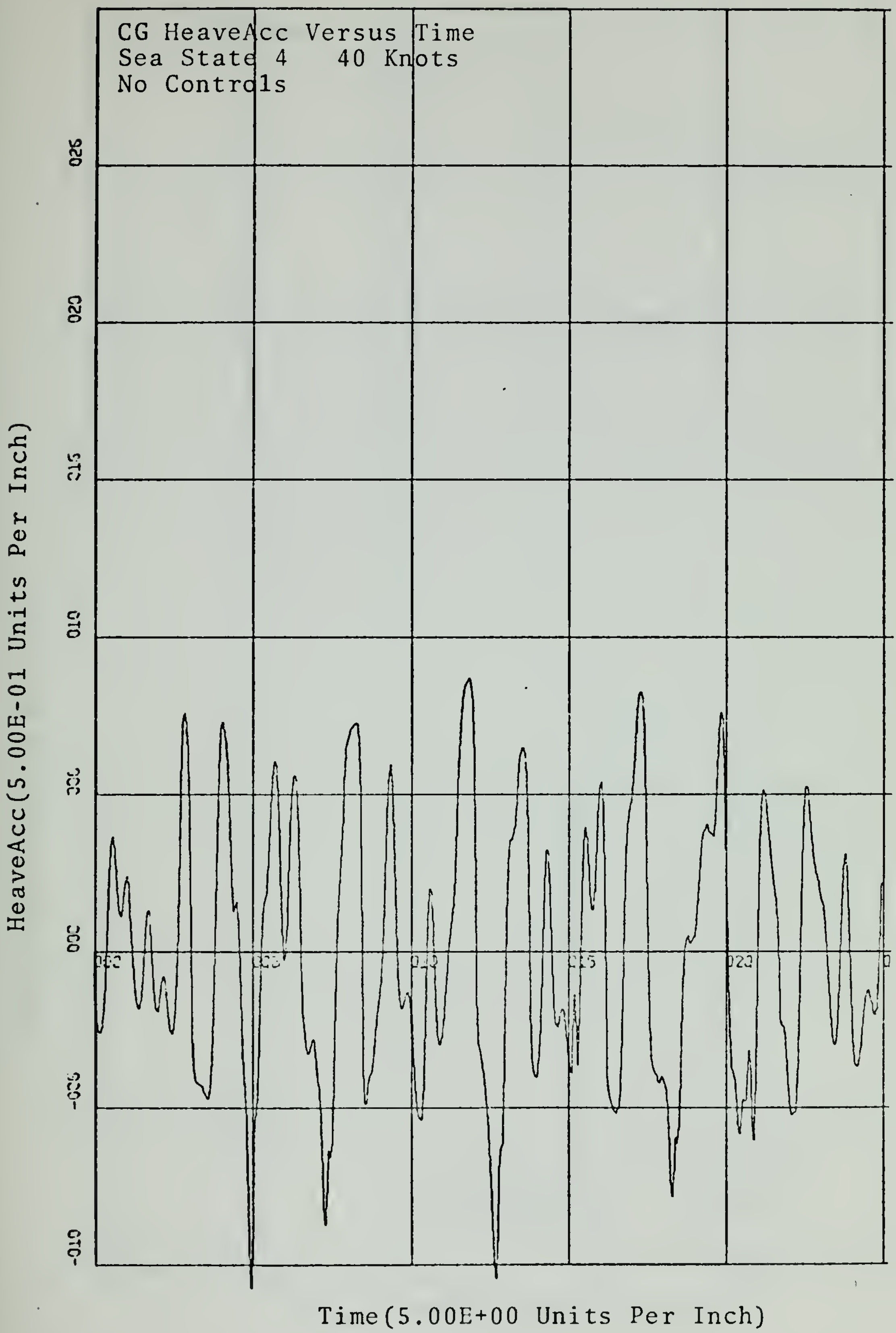

CG HeaveAcc Versus Time
Sea State 4 40 Knots
No Controls
HeaveAcc(5.00E-01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 82.

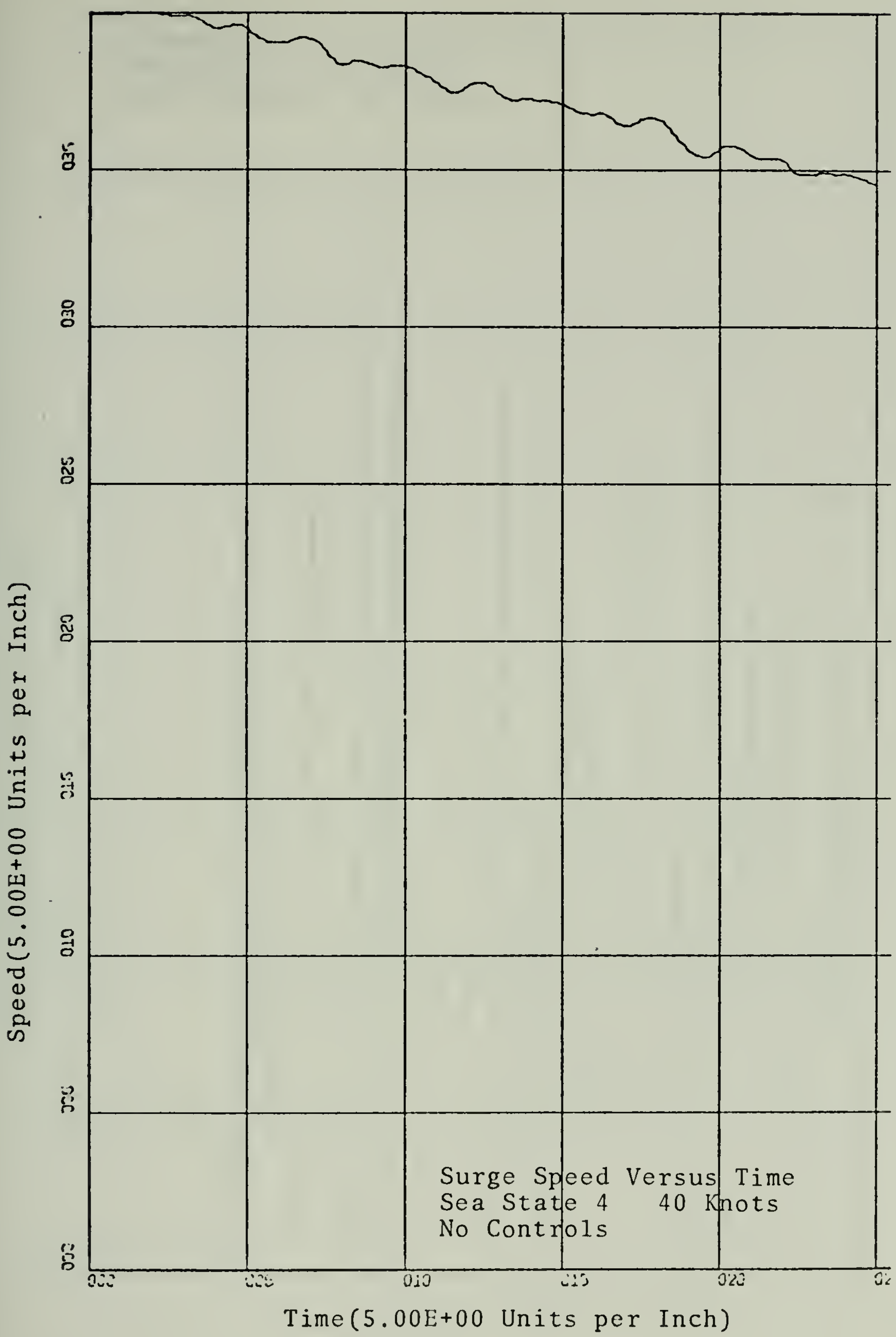
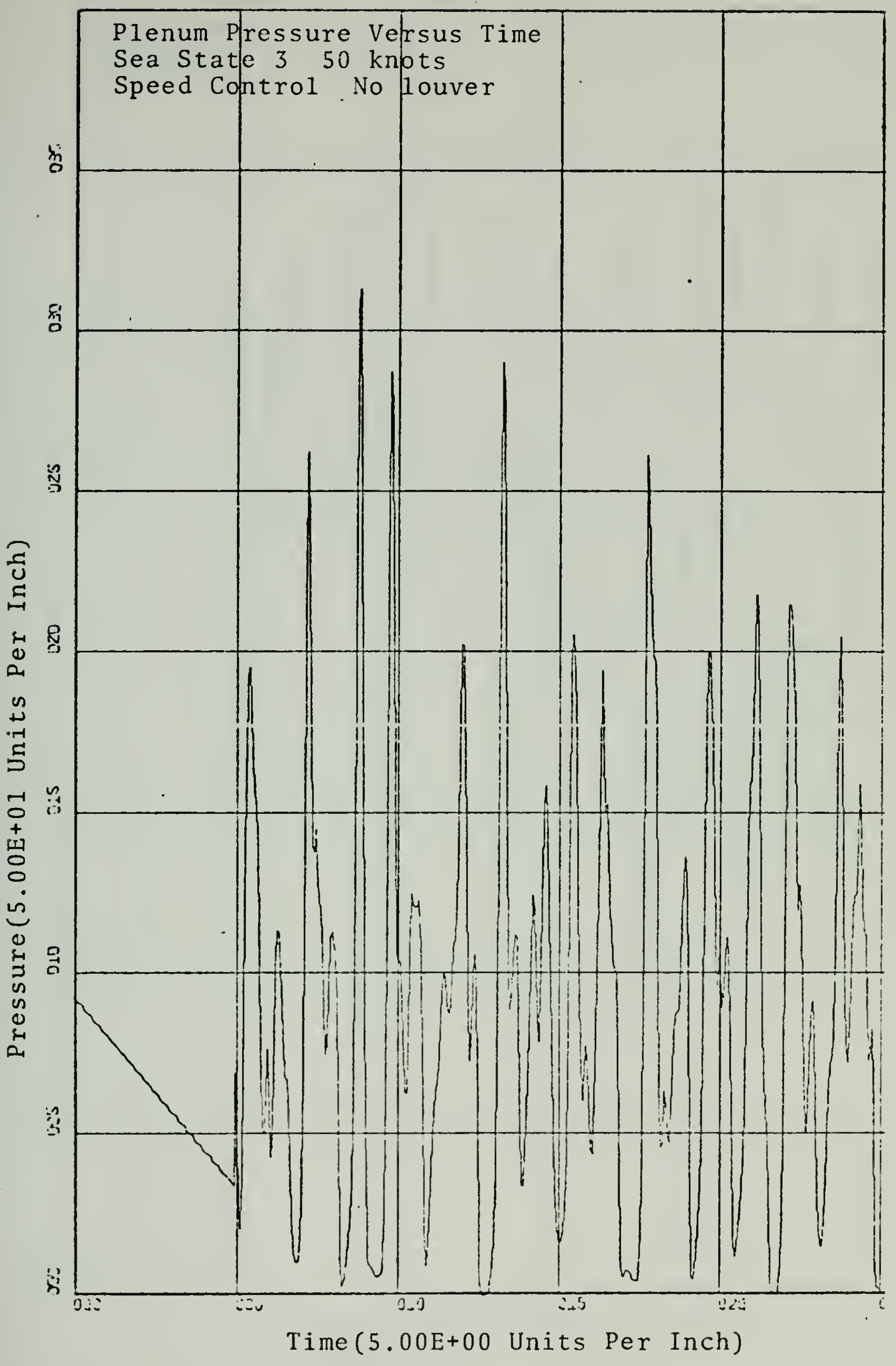
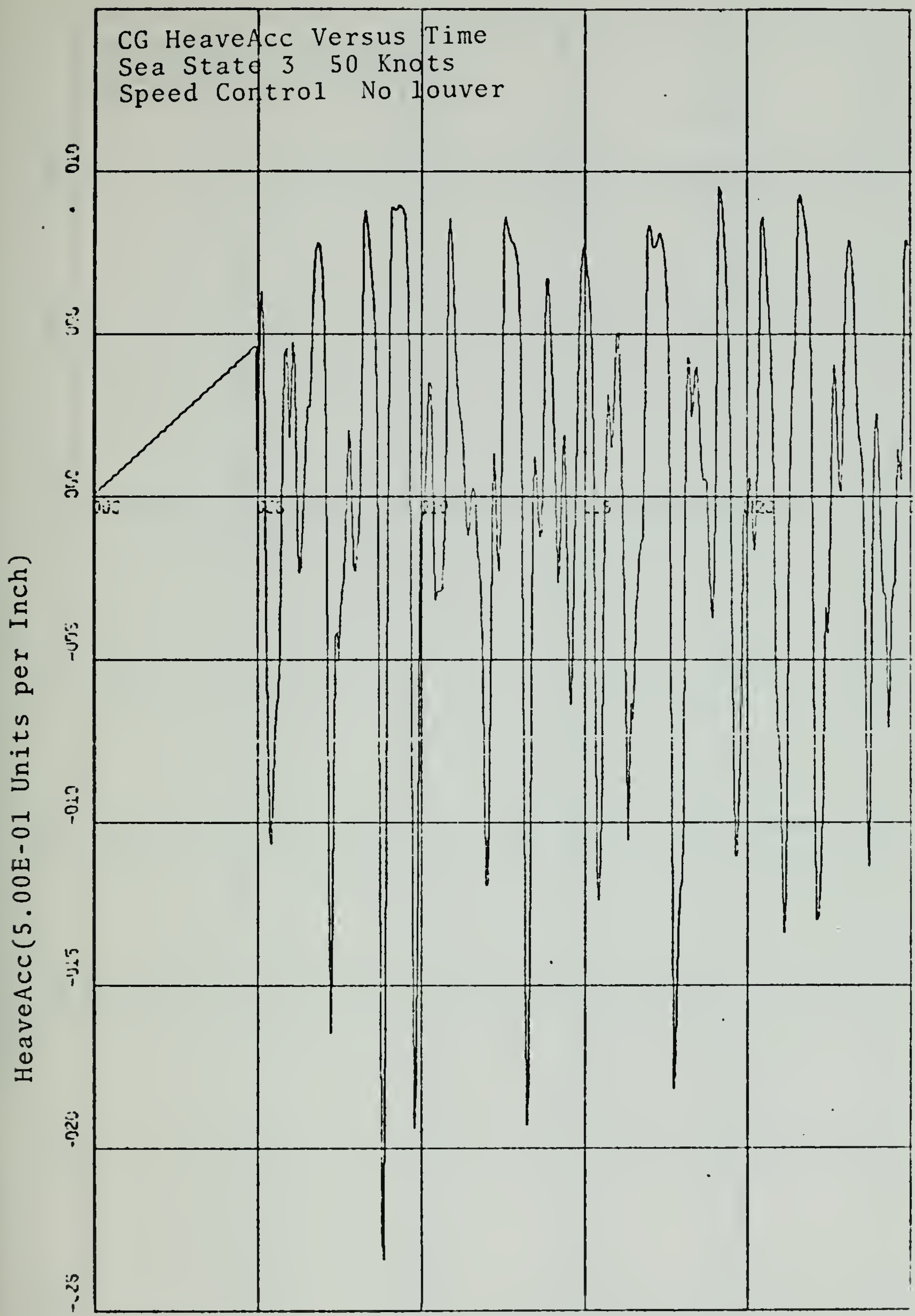

Surge Speed Versus Time
Sea State 4 40 Knots
No Controls
Speed(5.00E+00 Units per Inch)
Time(5.00E+00 Units per Inch)

Figure 83.



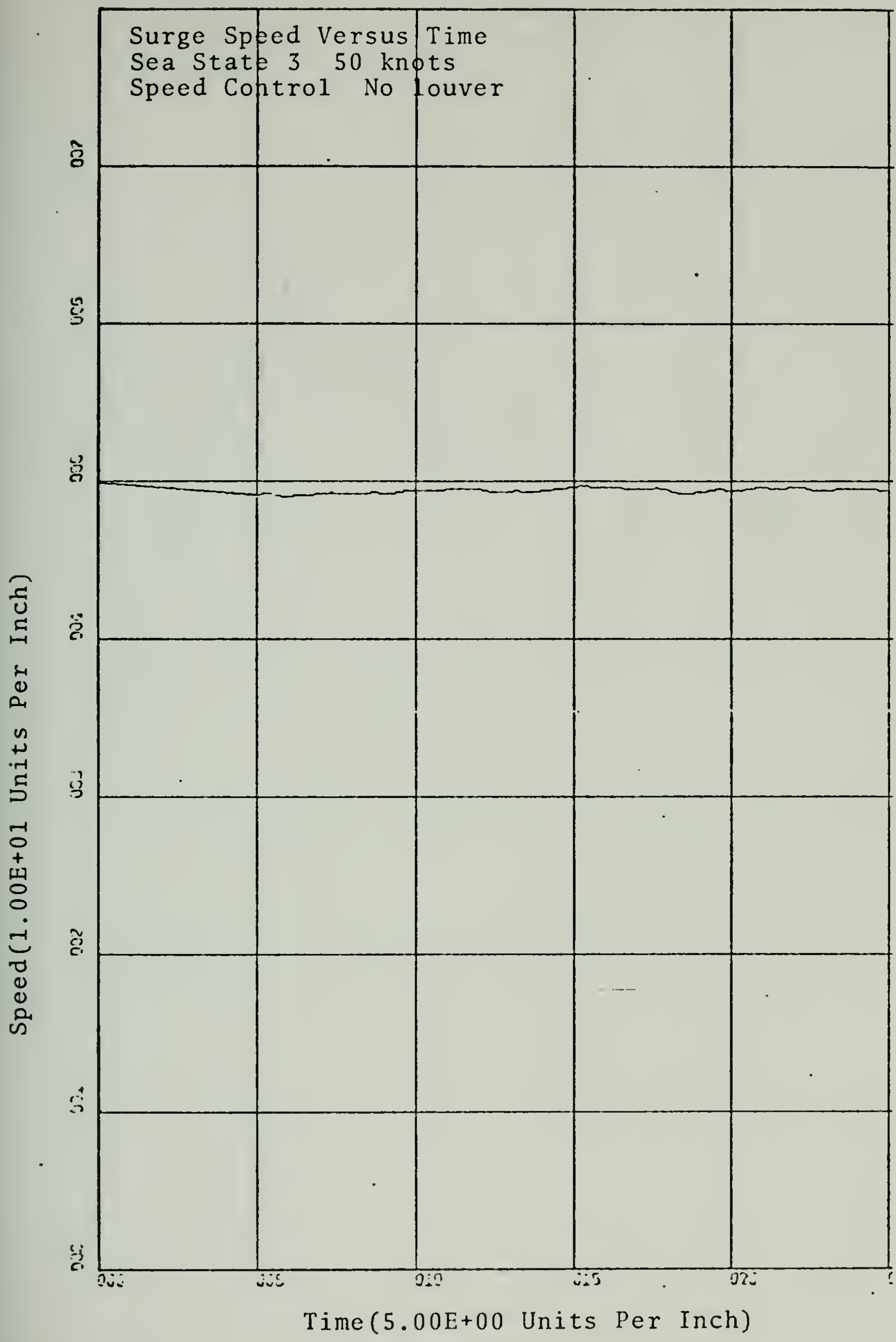
Plenum Pressure Versus Time
Sea State 3 50 knots
Speed Control No louver
Pressure(5.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 84.



Time(5.00E+00 Units Per Inch)

Figure 85.



Surge Speed Versus Time
Sea State 3 50 knots
Speed Control No louver
Speed(1.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 86.

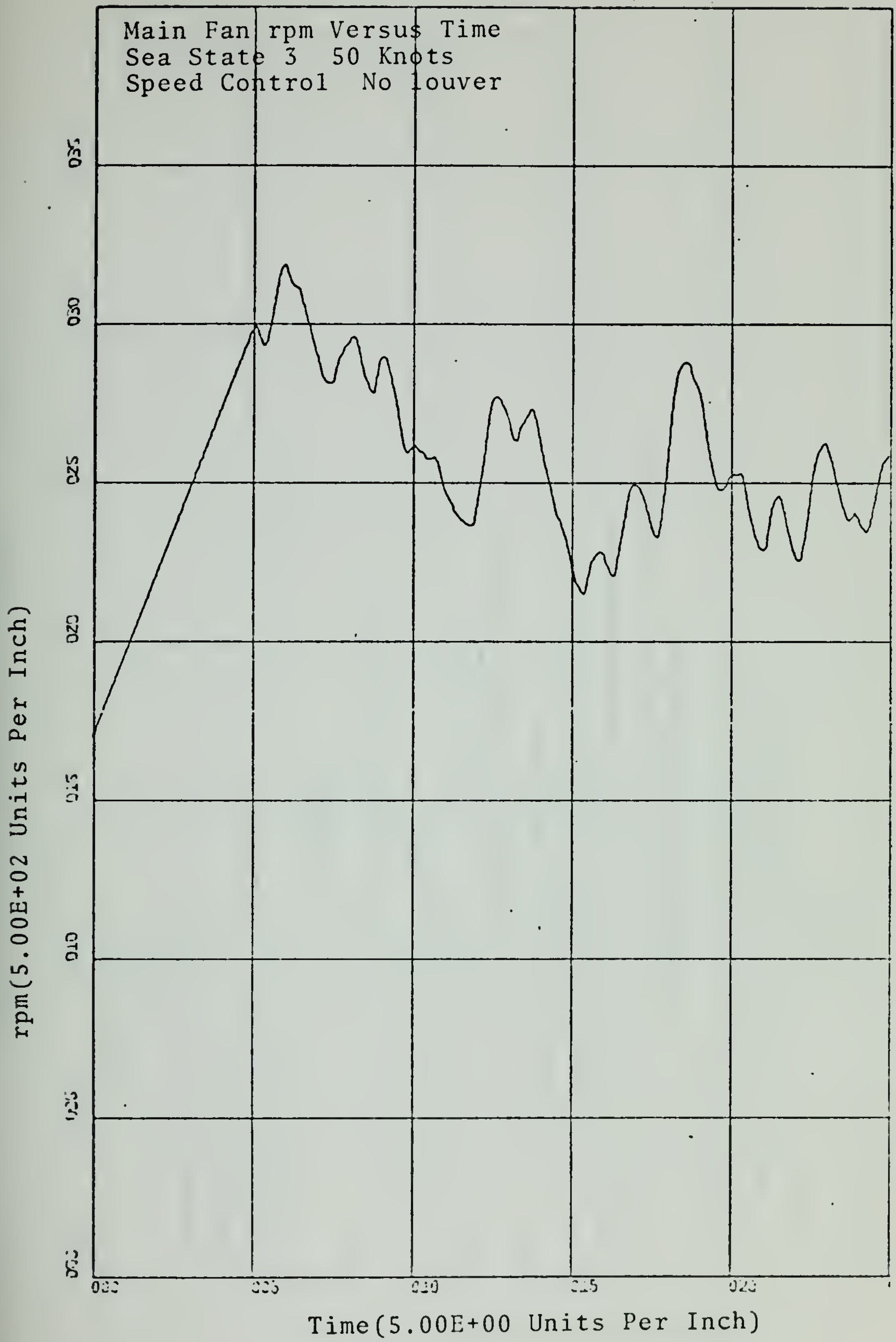

Main Fan rpm Versus Time
Sea State 3 50 Knots
Speed Control No louver
rpm(5.00E+02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 87.

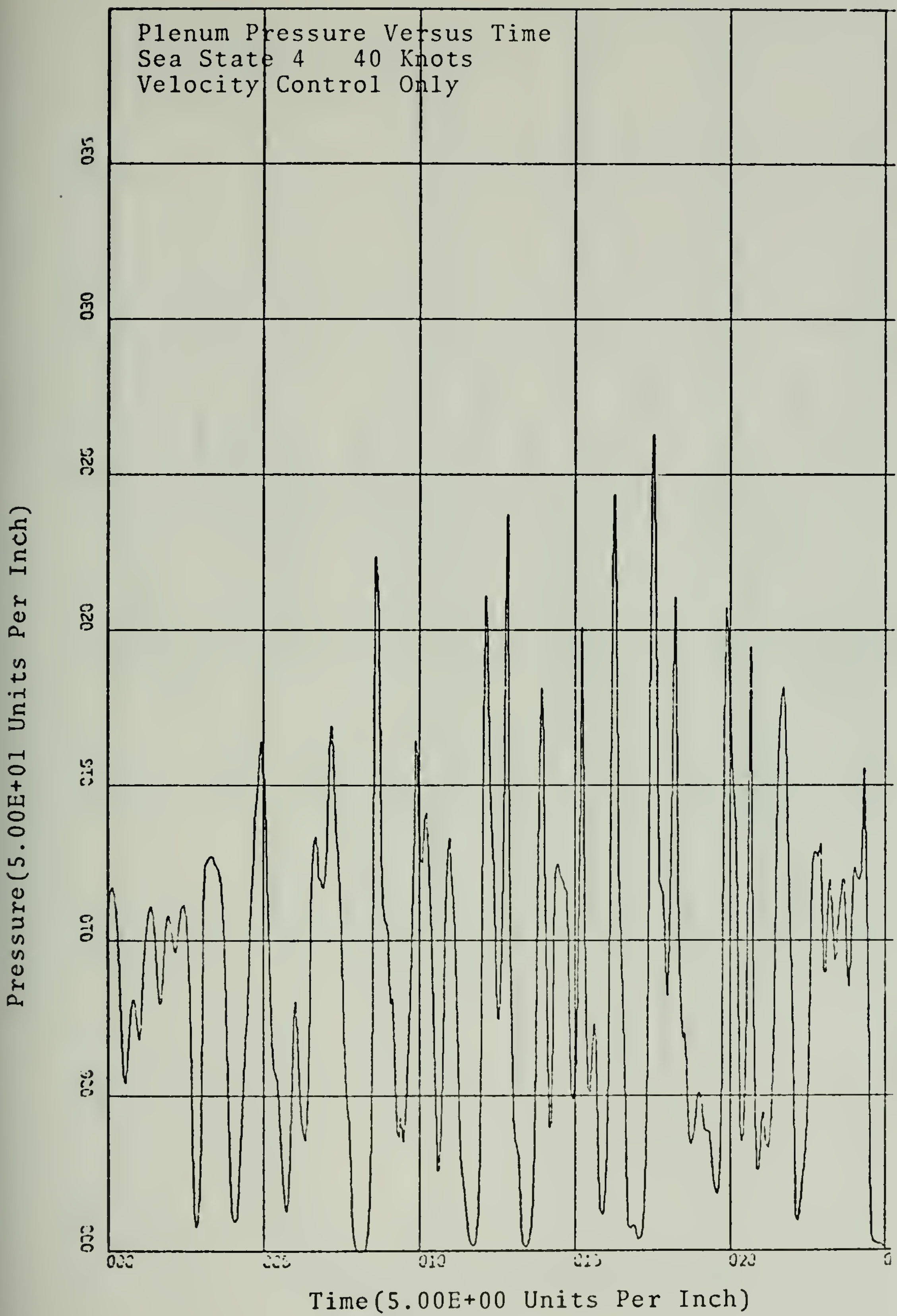

Plenum Pressure Versus Time
Sea State 4 40 Knots
Velocity Control Only
Pressure(5.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)
035
030
025
020
010
010
020

Figure 88.

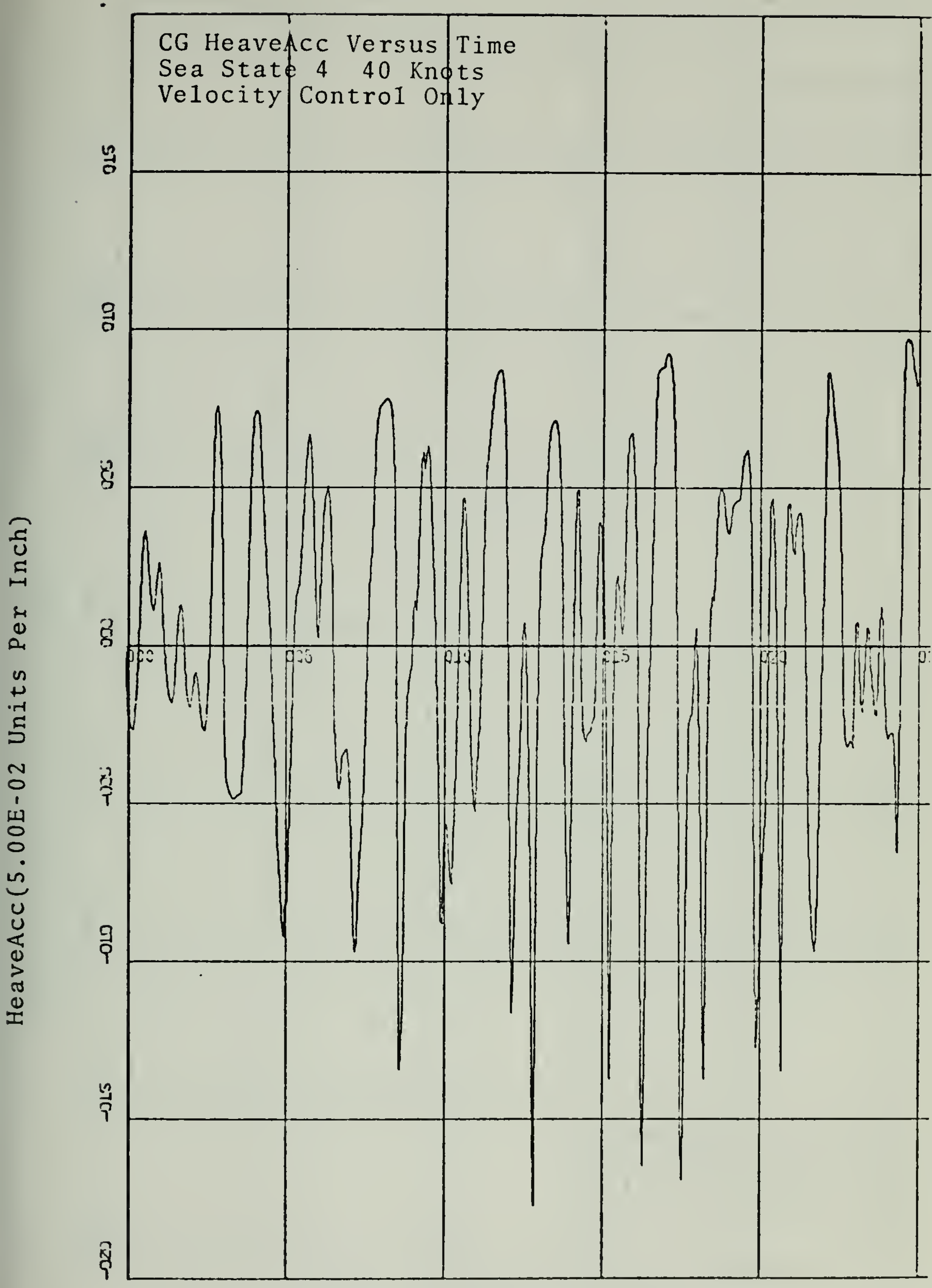
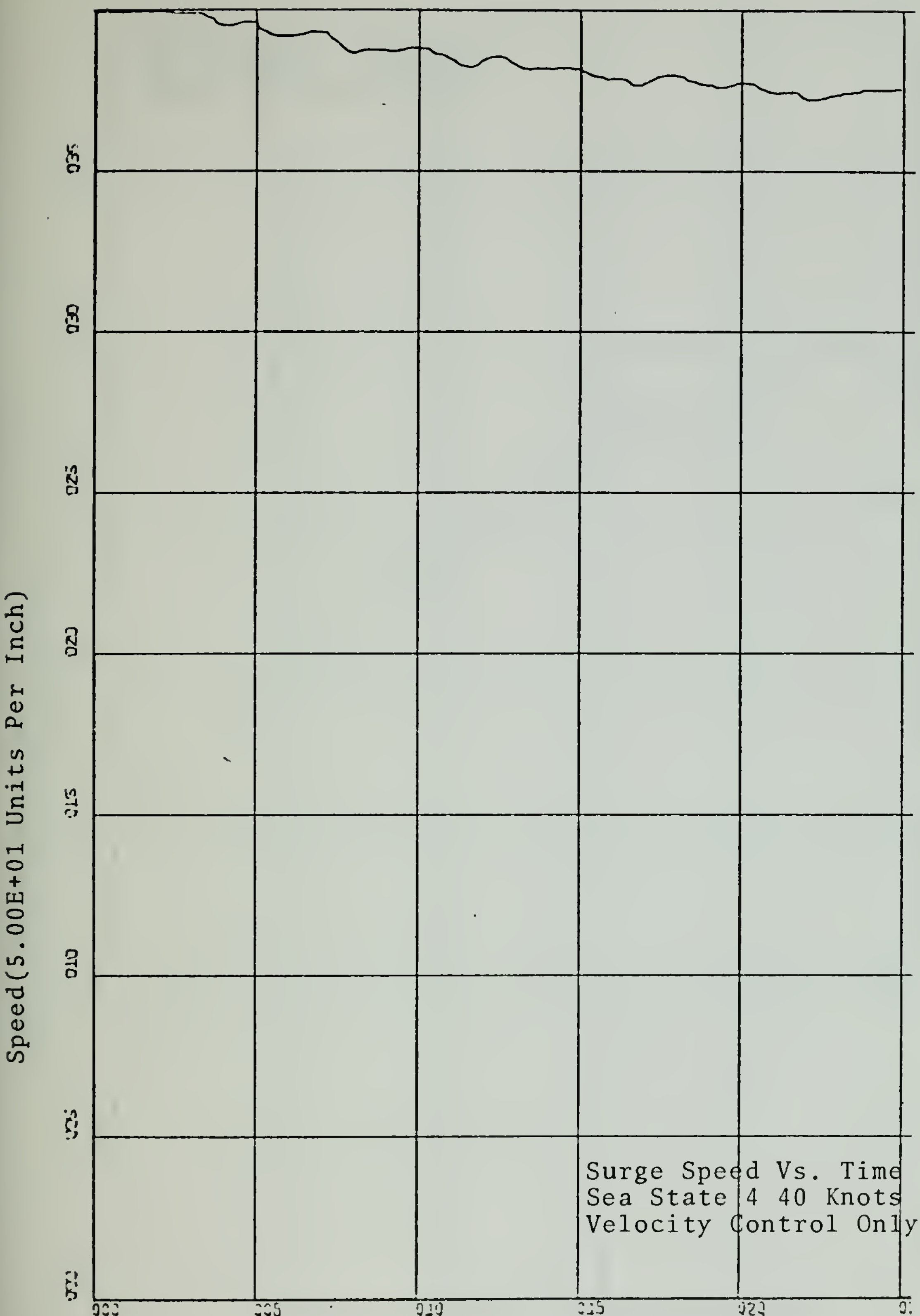

CG HeaveAcc Versus Time
Sea State 4 40 Knots
Velocity Control Only
HeaveAcc(5.00E-02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 89.



Time(5.00E+00 Units Per Inch)

Figure 90.

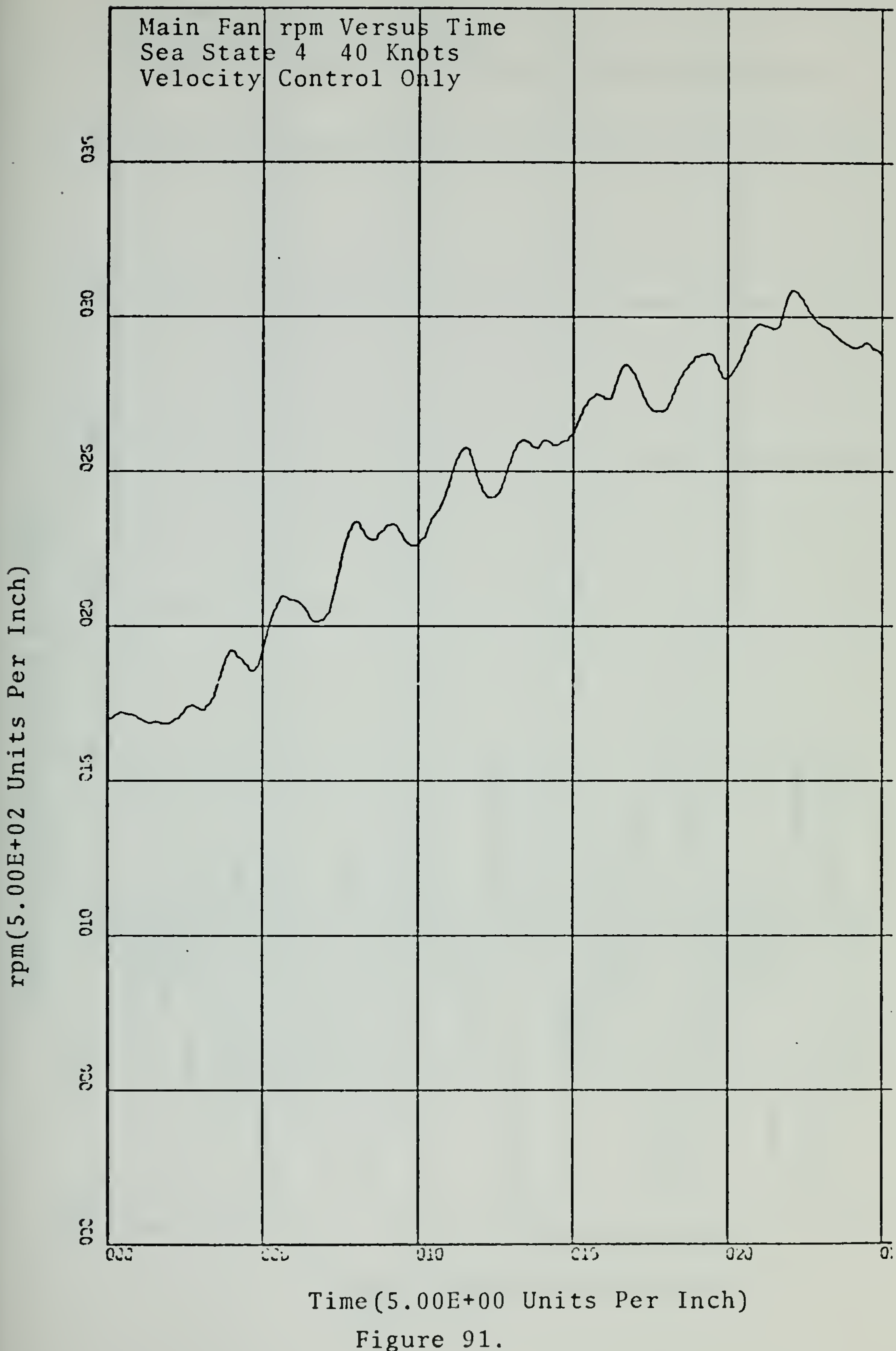
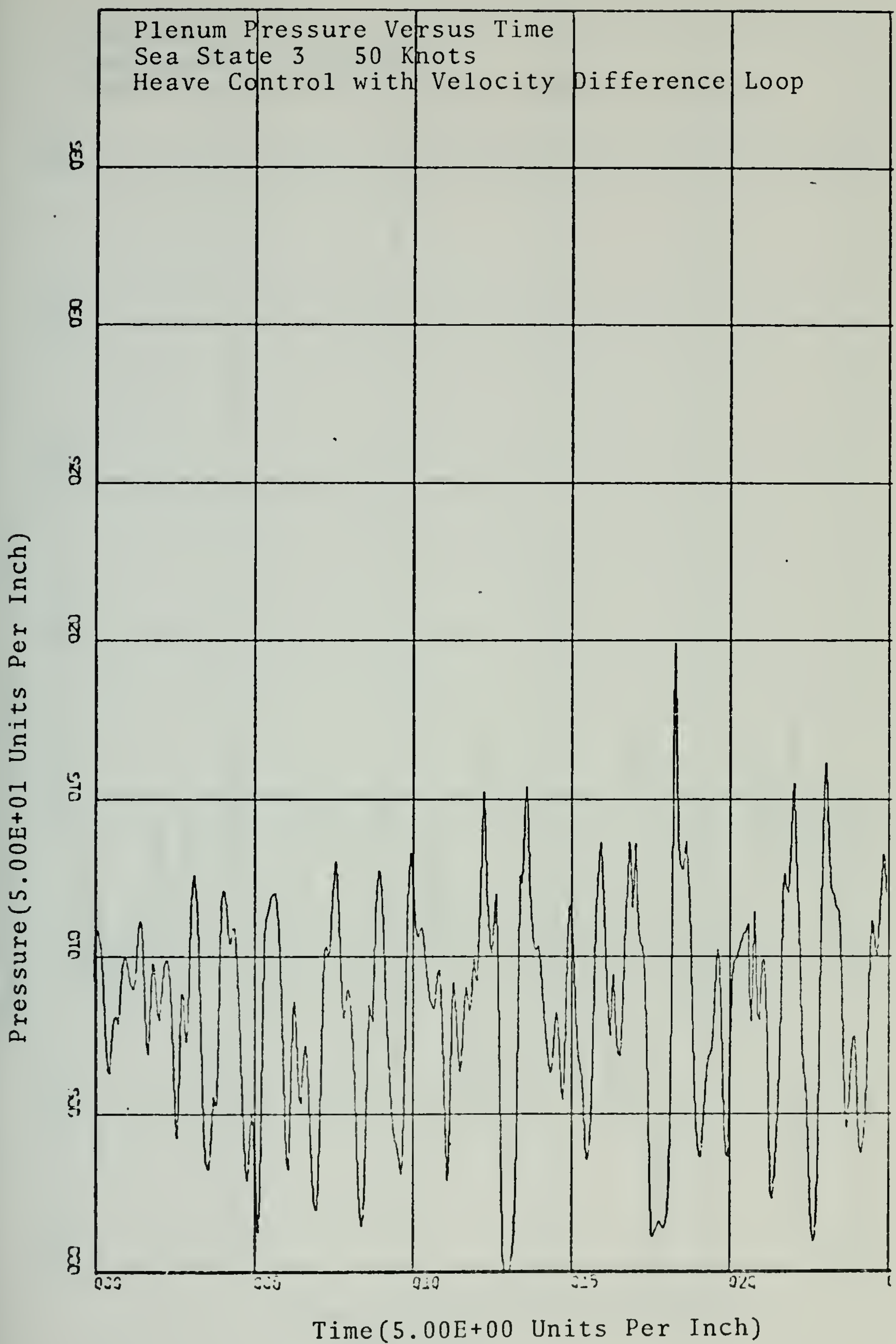

Main Fan rpm Versus Time
Sea State 4 40 Knots
Velocity Control Only
rpm(5.00E+02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 91.


Plenum Pressure Versus Time
Sea State 3 50 Knots
Heave Control with Velocity Difference Loop
Pressure(5.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)
Figure 92.

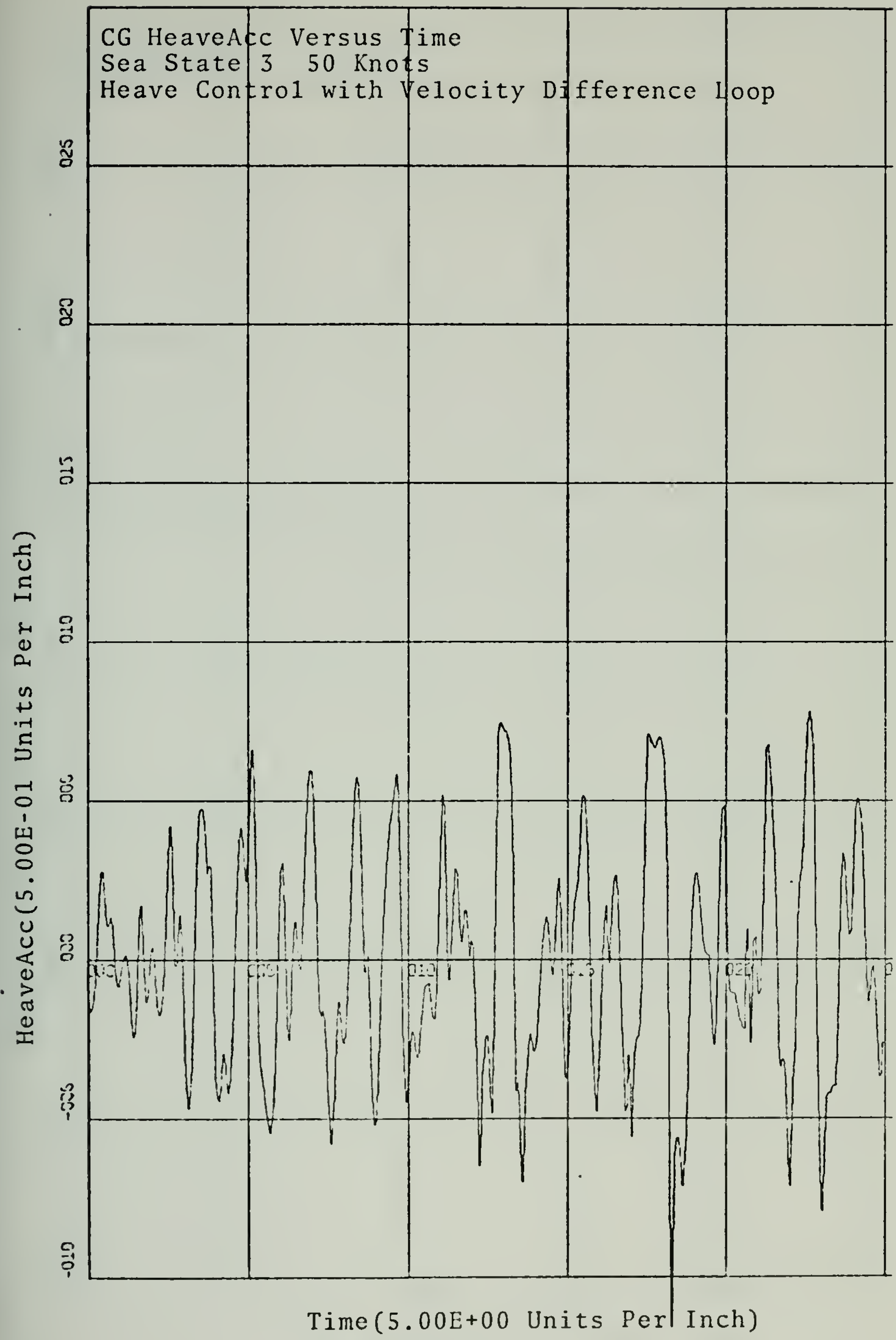

CG HeaveAcc Versus Time
Sea State 3 50 Knots
Heave Control with Velocity Difference Loop
HeaveAcc(5.00E-01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 93.

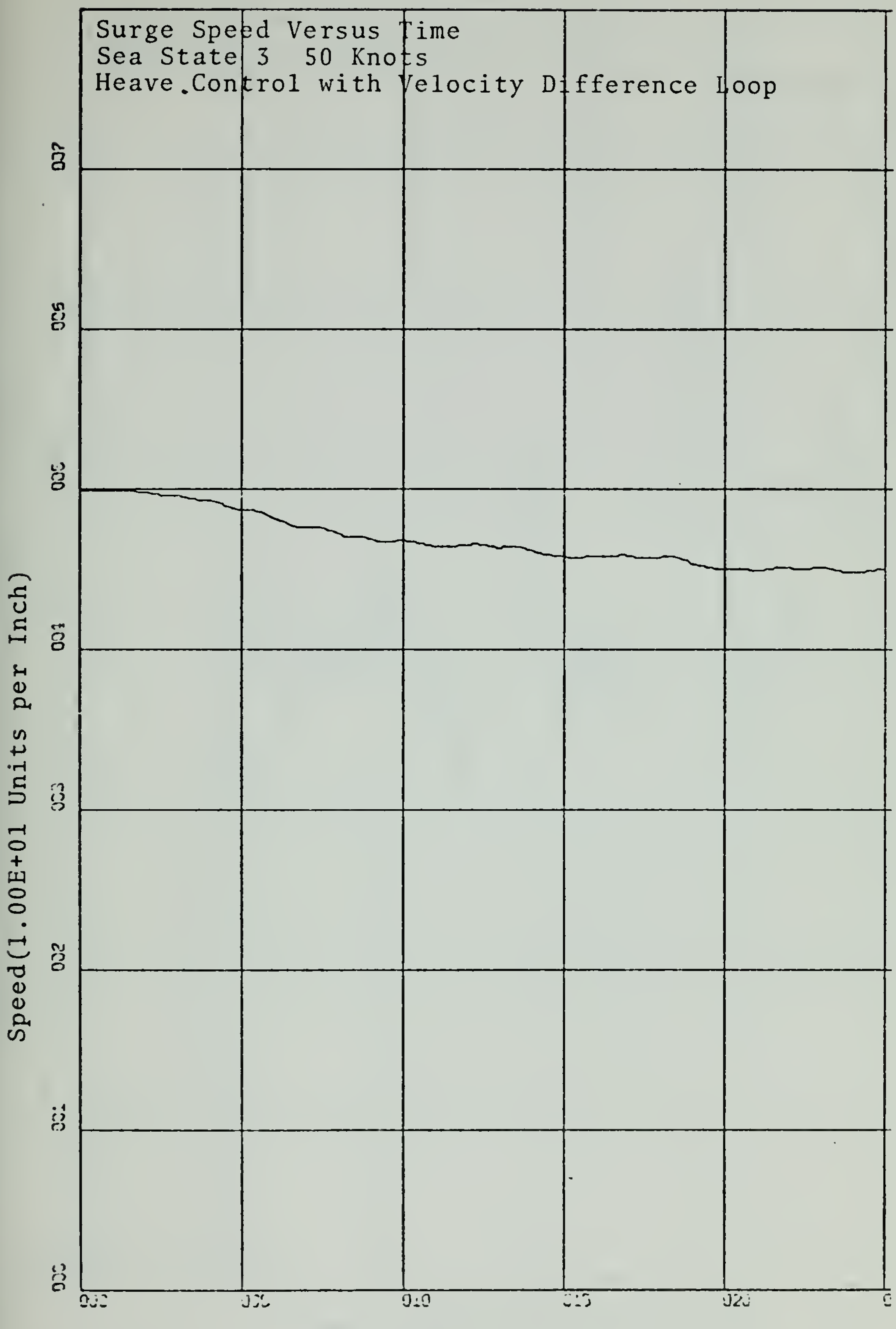

Surge Speed Versus Time
Sea State 3 50 Knots
Heave Control with Velocity Difference Loop
Speed(1.00E+01 Units per Inch)
Time(5.00E+00 Units Per Inch)

Figure 94.

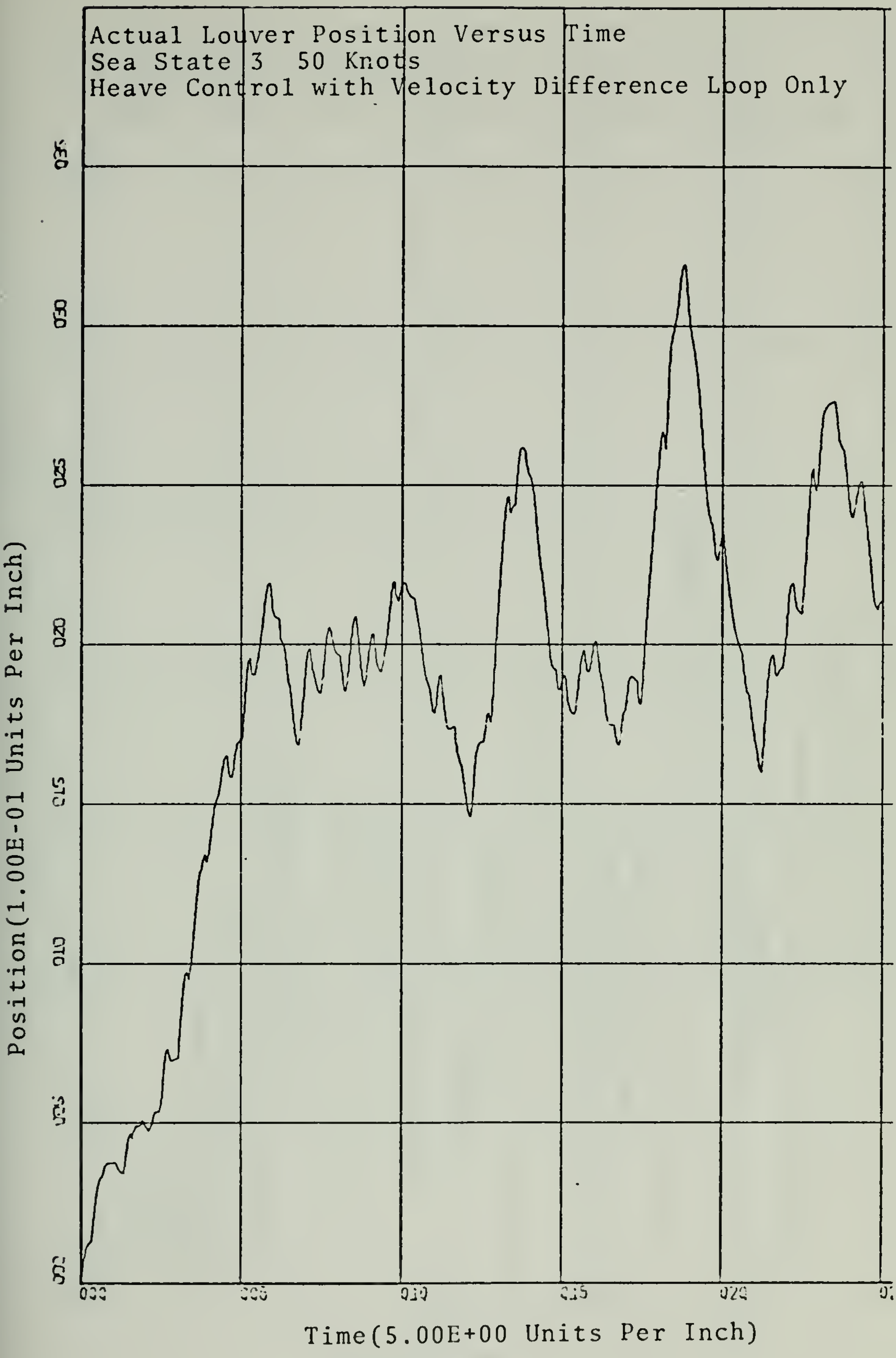

Actual Louver Position Versus Time
Sea State 3 50 Knots
Heave Control with Velocity Difference Loop Only
Position(1.00E-01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 95.

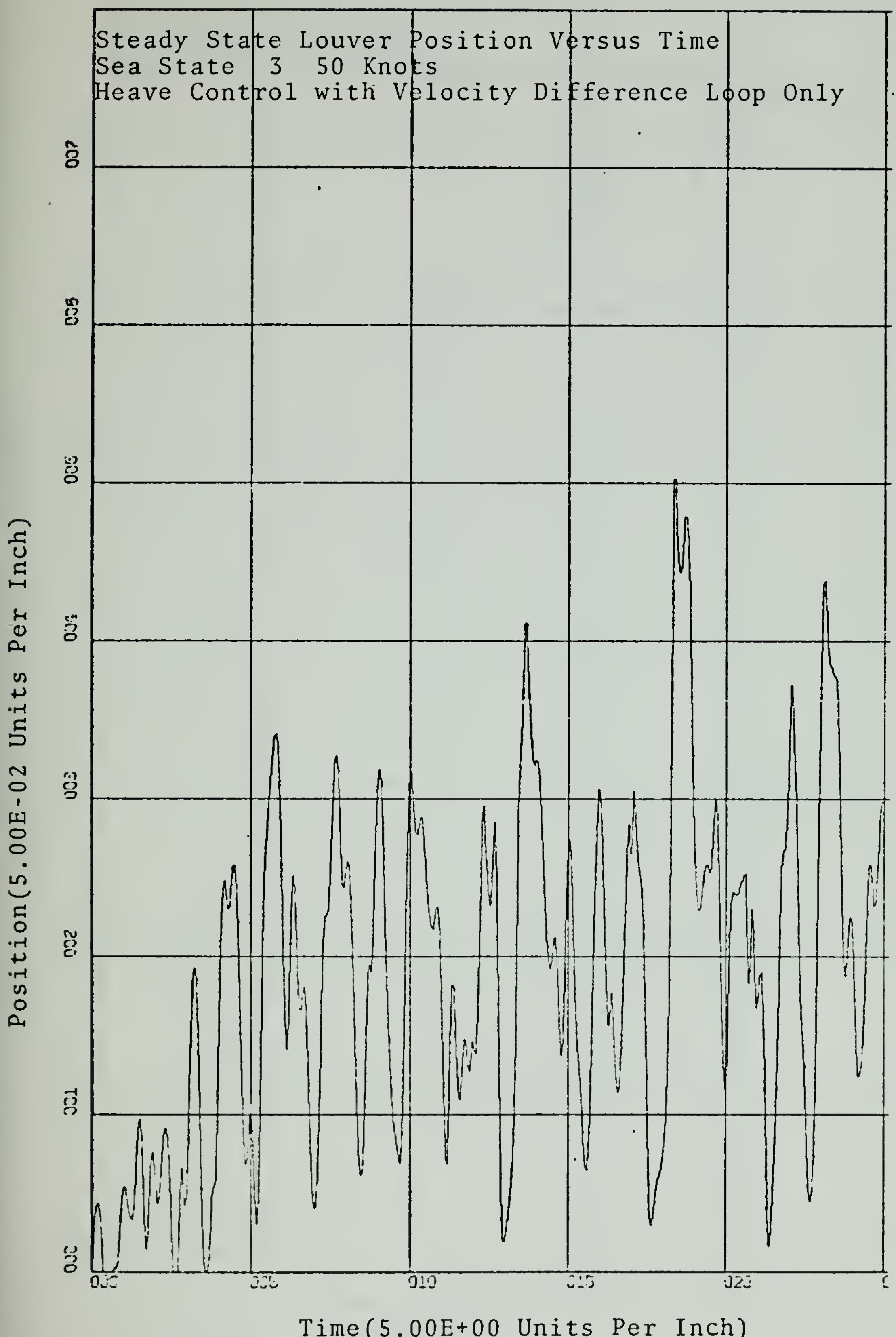

Steady State Louver Position Versus Time
Sea State 3 50 Knots
Heave Control with Velocity Difference Loop Only
Position(5.00E-02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 96.

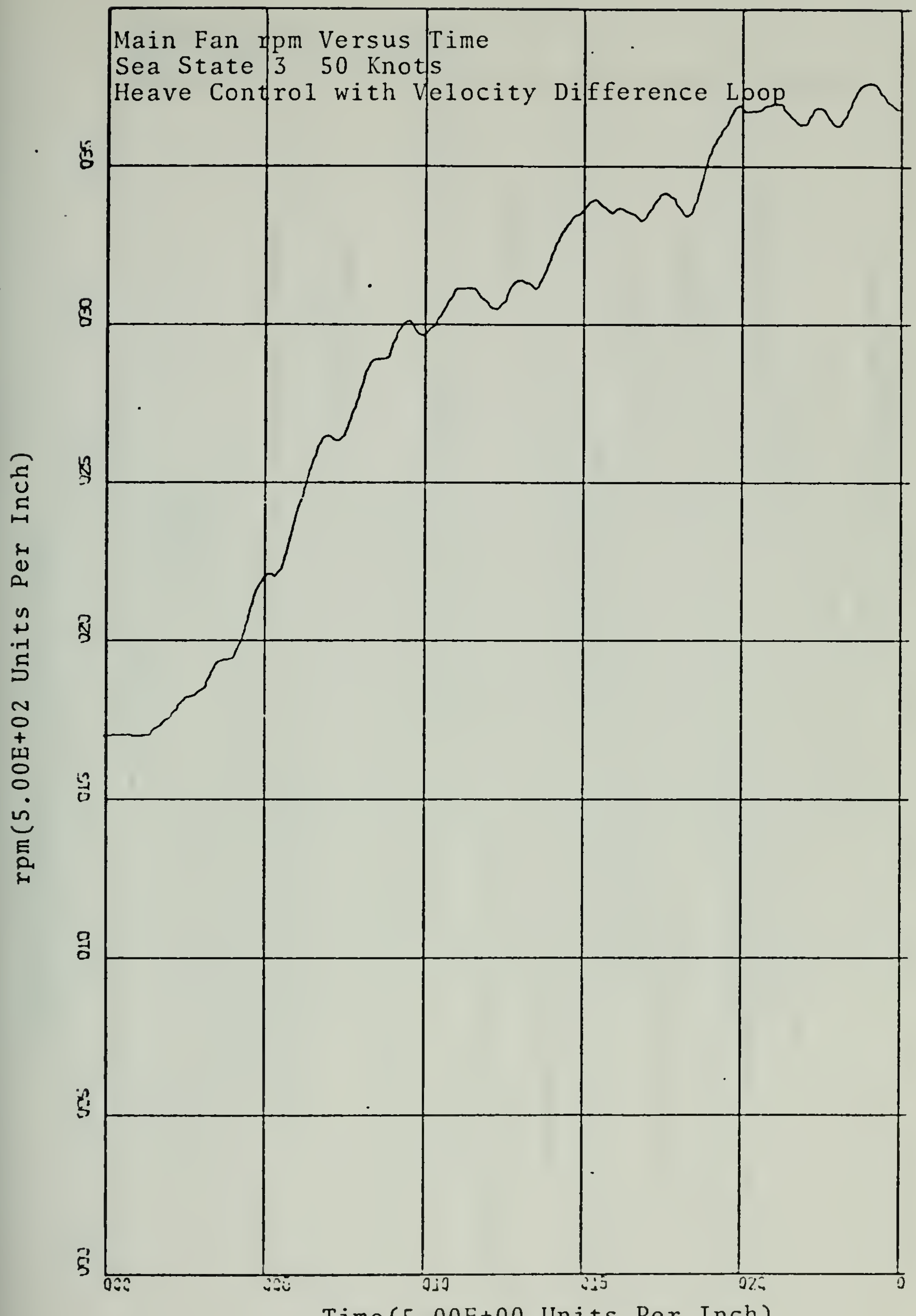

Main Fan rpm Versus Time
Sea State 3 50 Knots
Heave Control with Velocity Difference Loop
rpm(5.00E+02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 97.

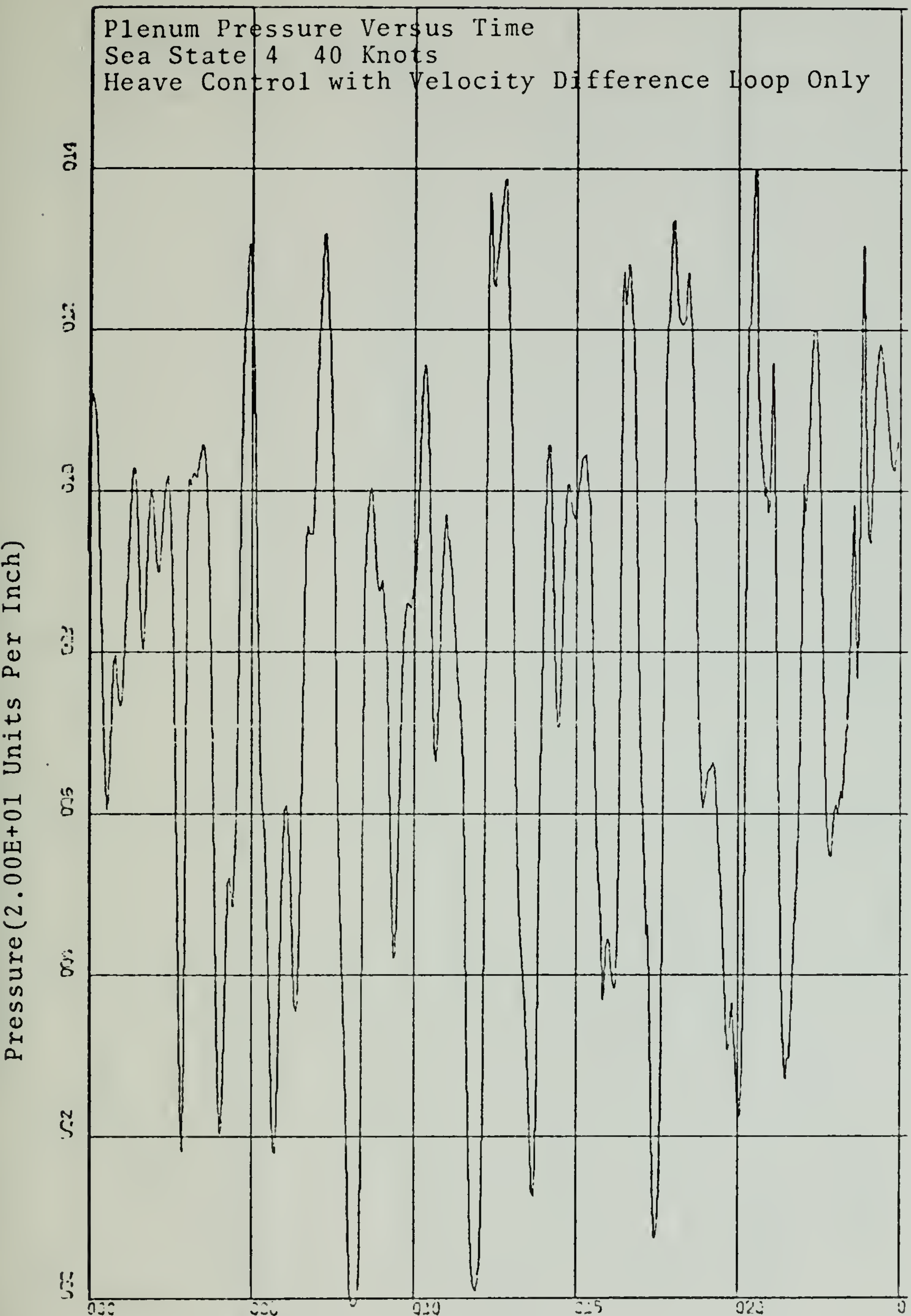

Plenum Pressure Versus Time
Sea State 4 40 Knots
Heave Control with Velocity Difference Loop Only
Pressure(2.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 98.

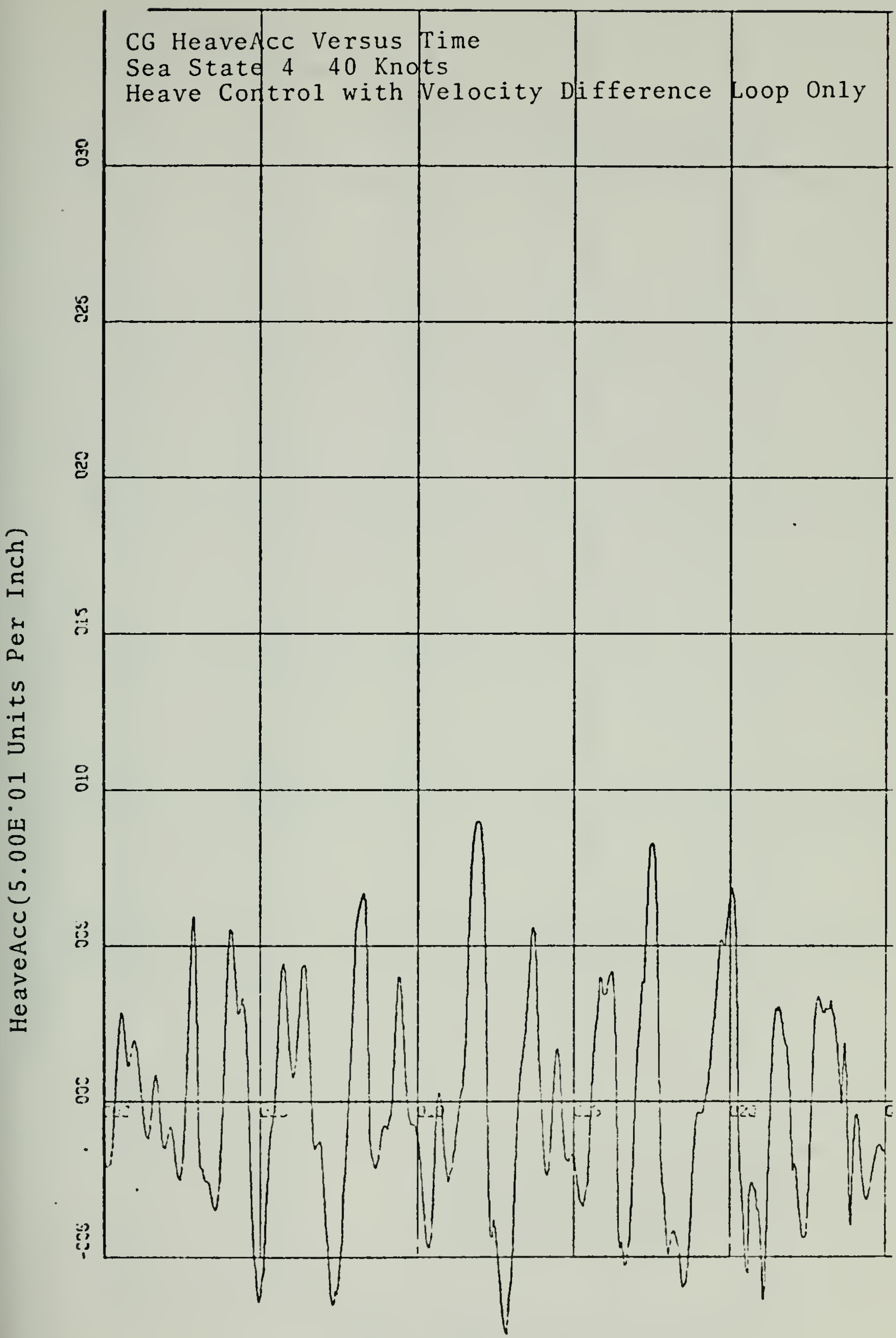

CG HeaveAcc Versus Time
Sea State 4 40 Knots
Heave Control with Velocity Difference Loop Only
HeaveAcc(5.00E'01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 99.

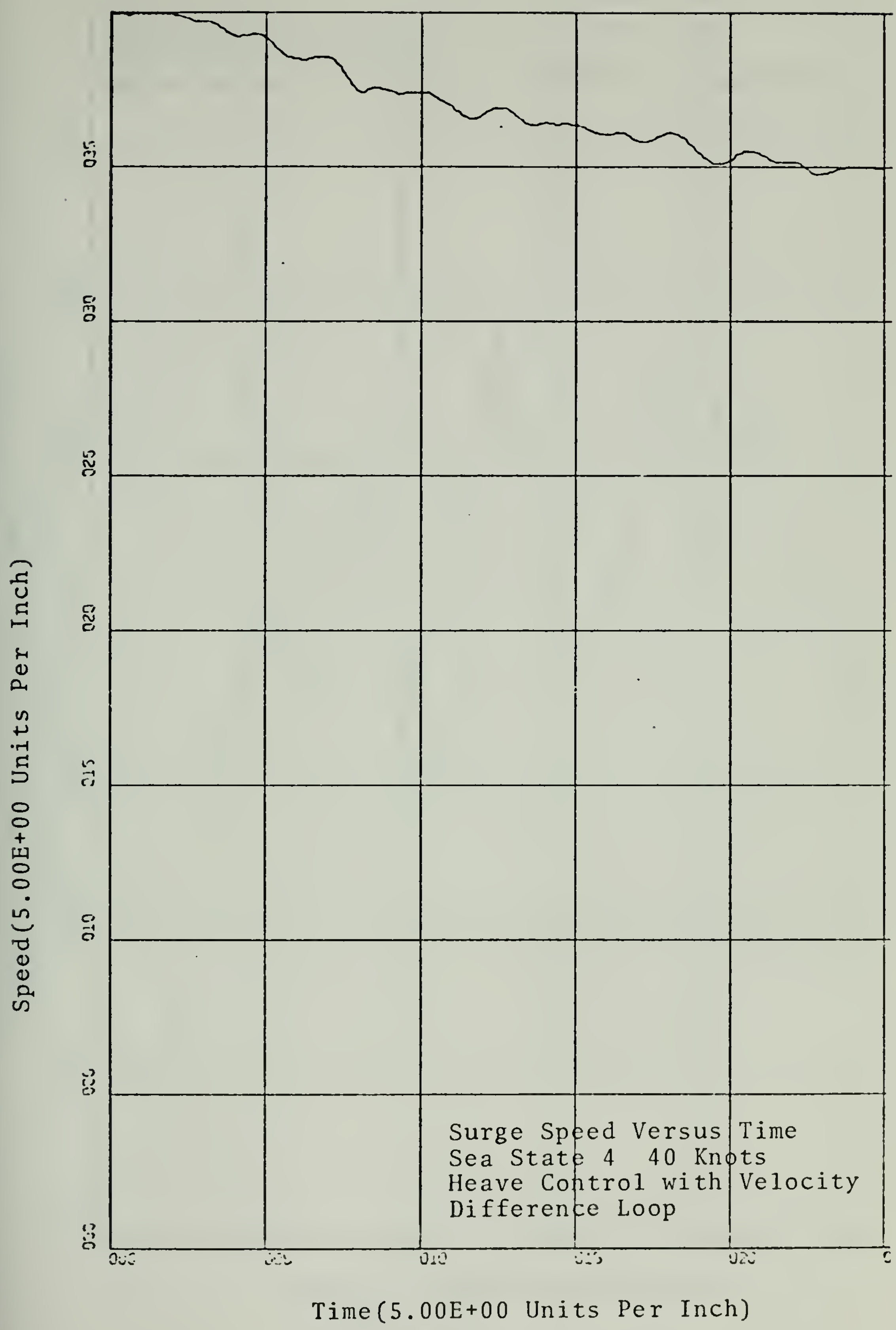

Speed(5.00E+00 Units Per Inch)
Time(5.00E+00 Units Per Inch)
Surge Speed Versus Time
Sea State 4 40 Knots
Heave Control with Velocity
Difference Loop

Figure 100.

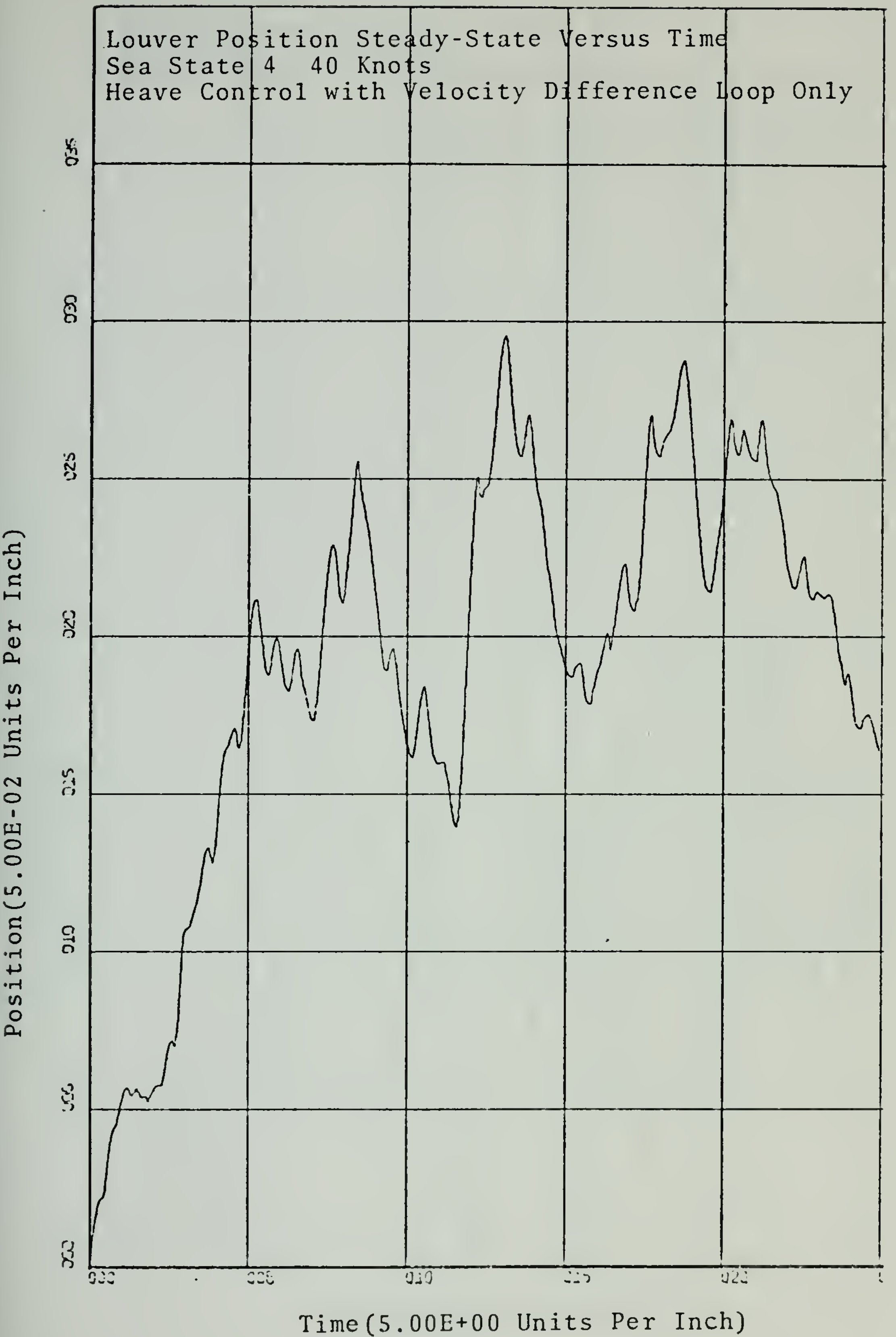
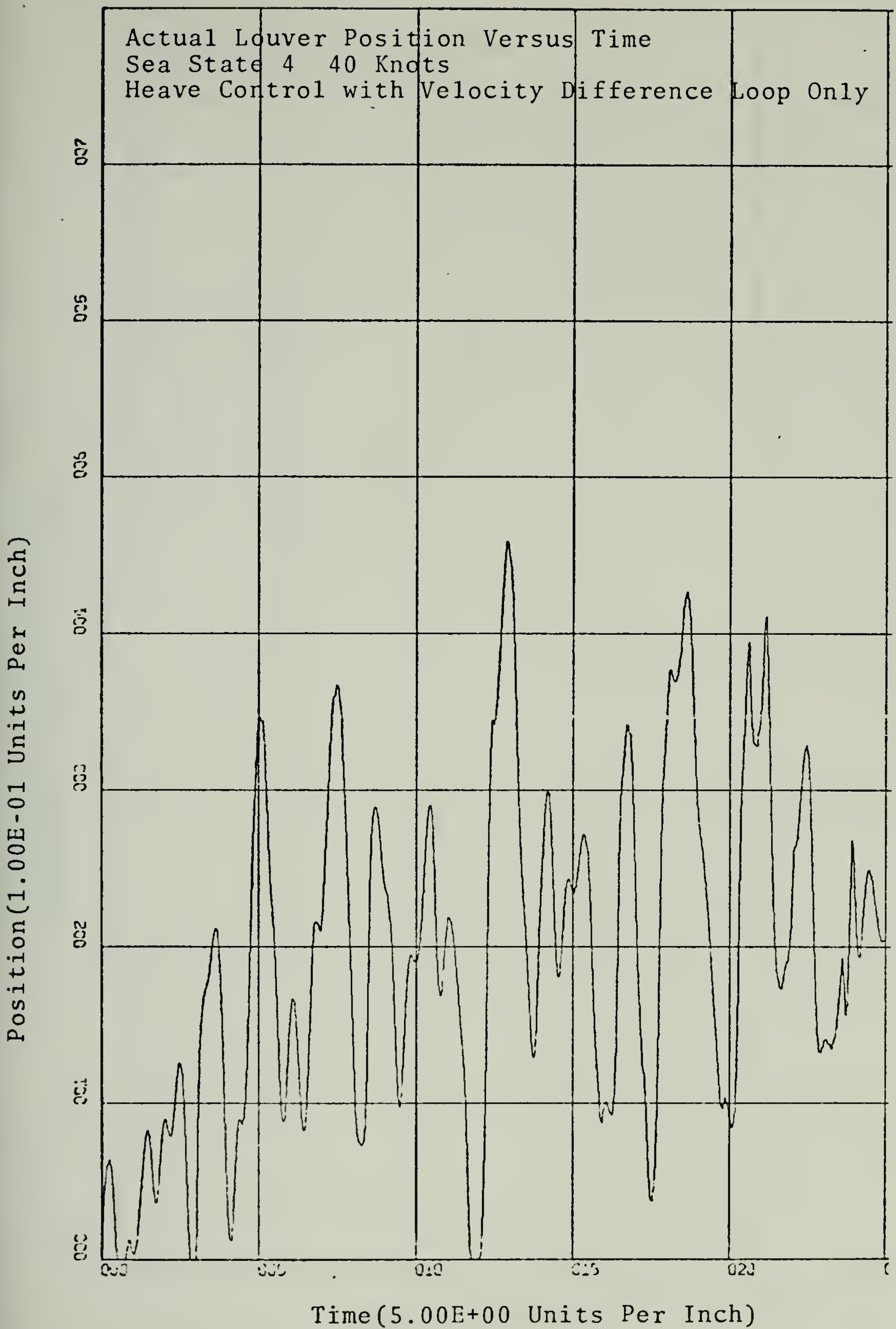
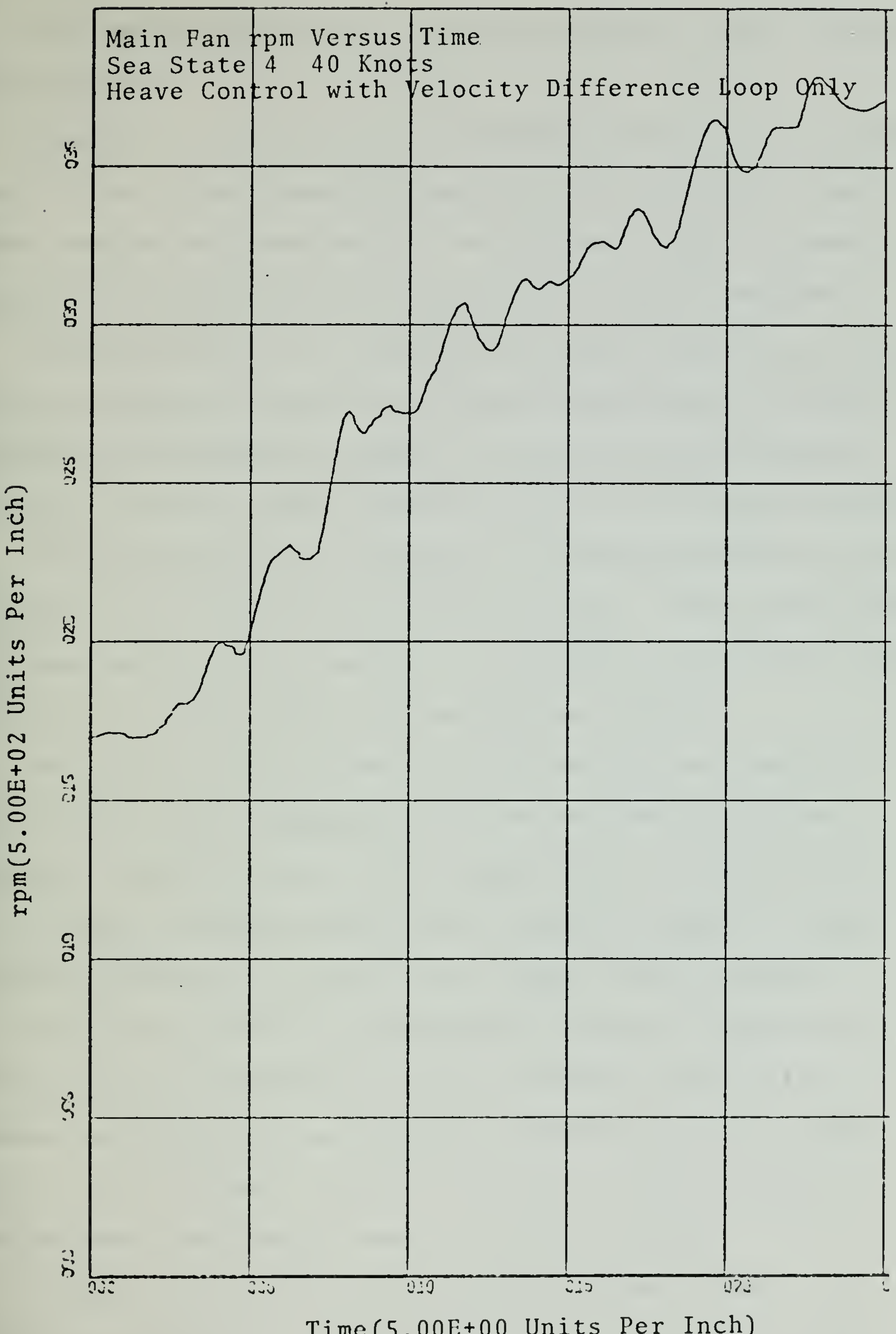

Louver Position Steady-State Versus Time
Sea State 4 40 Knots
Heave Control with Velocity Difference Loop Only
Position(5.00E-02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 101.



Actual Louver Position Versus Time
Sea State 4 40 Knots
Heave Control with Velocity Difference Loop Only
Position(1.00E-01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 102.



Main Fan rpm Versus Time
Sea State 4 40 Knots
Heave Control with Velocity Difference Loop Only
rpm(5.00E+02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 103.

4. Heave control with completed velocity loop, Figures 104 to 115.

Graphs for runs with just the heave control are not available. Due to the excessive venting, both sea states runs were terminated prematurely. As with the single frequency runs, all simulation are of twenty-five second duration.

The desirability of investigation under sea state conditions is quickly evident, the heave accelerations are more intense and completely random; increased drag and venting creates a swift, steady deterioration of the forward velocity.

This degradation of velocity was checked quickly by the addition of the velocity difference loop. Without the louver system, however, the increase of the heave acceleration particularly in the negative direction was marked.

When the louver system was introduced, these heave accelerations were dampened, but some degradation of the average velocity can be noted, especially in the Sea State 4 - 40 knot run where the forward velocity appears to have leveled off after a total loss of about twelve percent.

The results from the simulations with the complete control system in operations shown excellent speed control. Heave accelerations have greatly improved over those runs with only the speed control functioning and are comparable or improved over those results with no controls.

Because the total venting area had shown itself to be important during the investigation of the single frequency sinusoidal waves, a single simulation run in which the lower area was increased by sixty-six percent to 16' by 15'

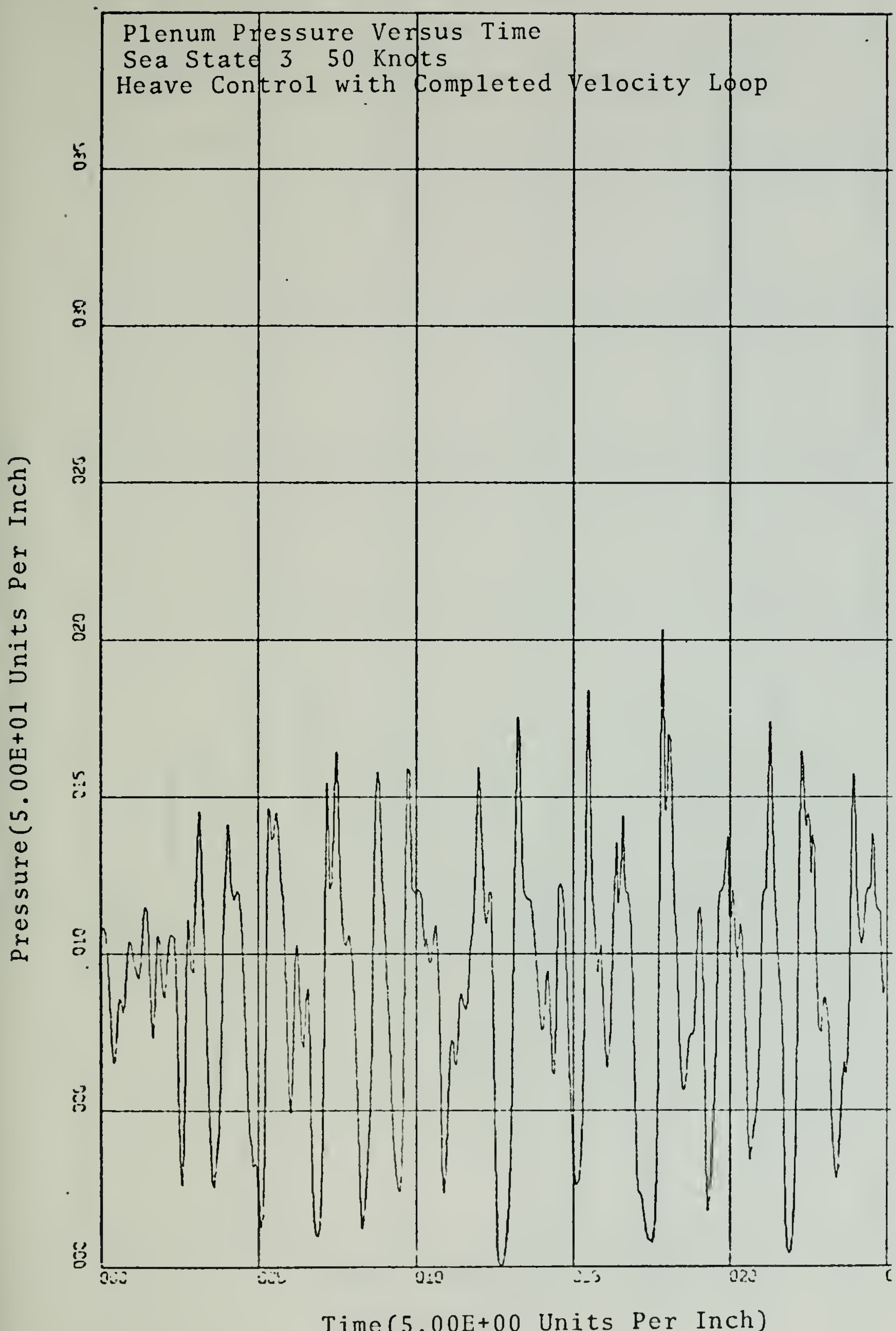
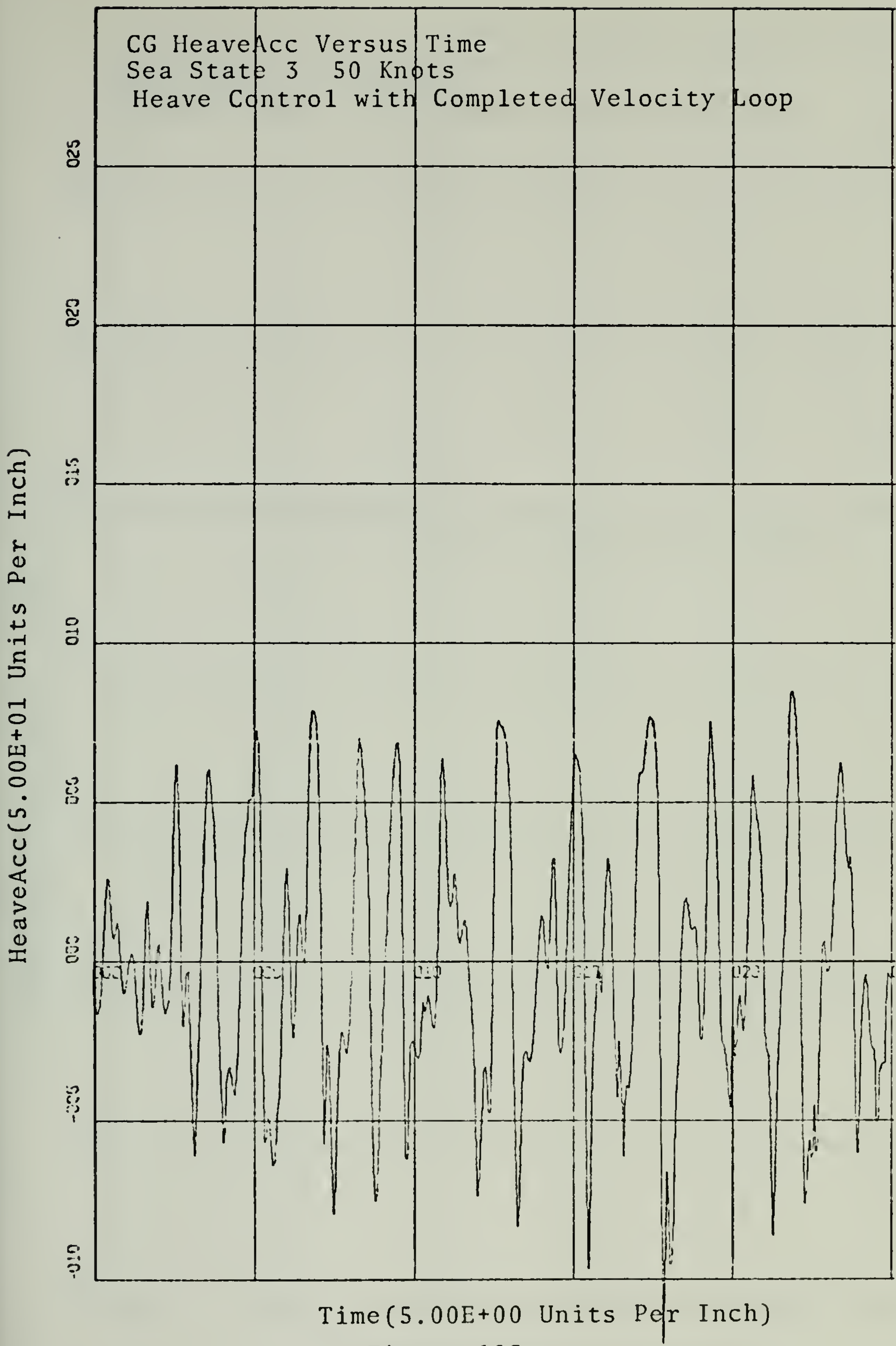

Plenum Pressure Versus Time
Sea State 3 50 Knots
Heave Control with Completed Velocity Loop
Pressure(5.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 104.



CG HeaveAcc Versus Time
Sea State 3 50 Knots
Heave Control with Completed Velocity Loop
HeaveAcc(5.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 105.

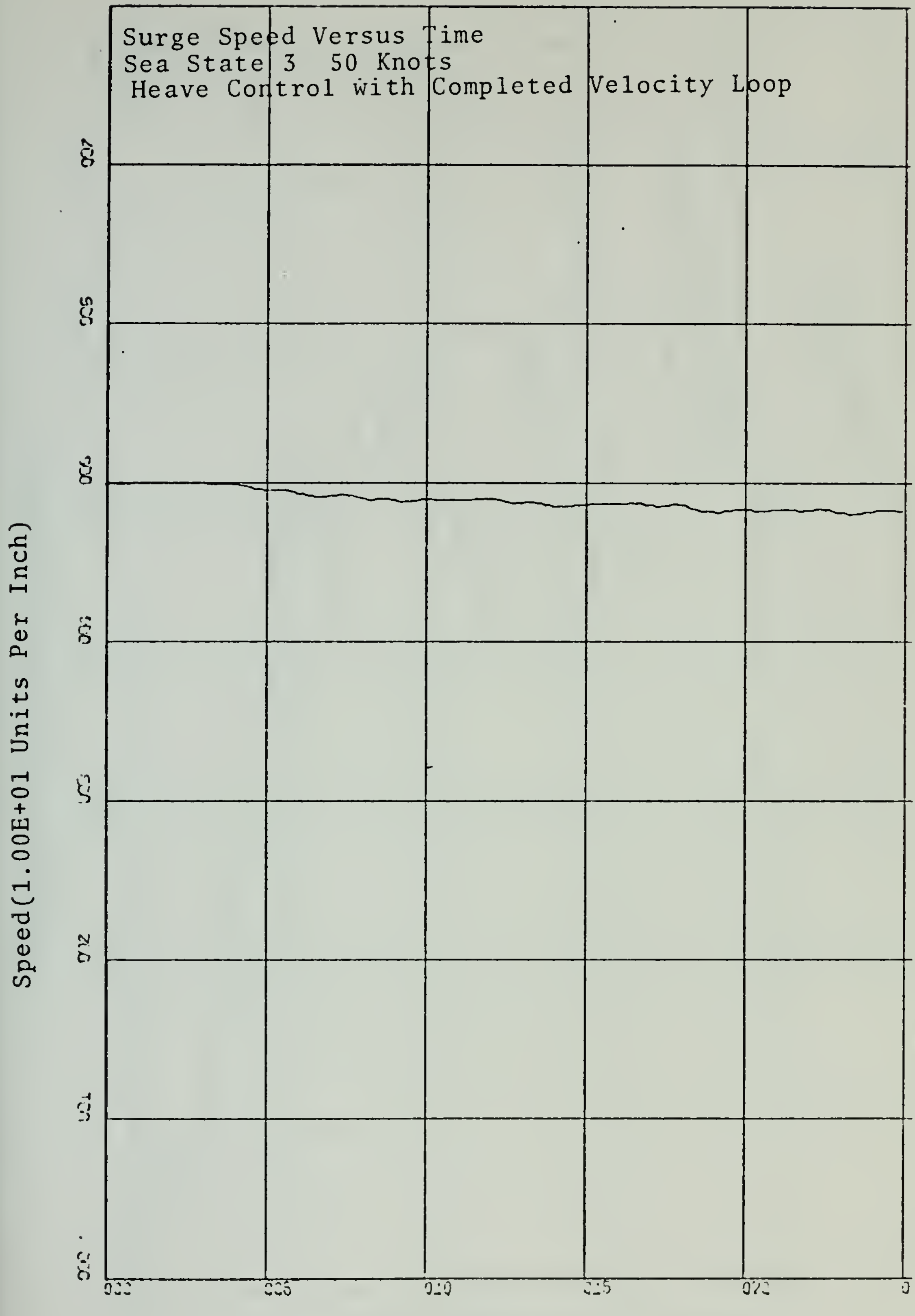

Surge Speed Versus Time
Sea State 3 50 Knots
Heave Control with Completed Velocity Loop
Speed(1.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 106.

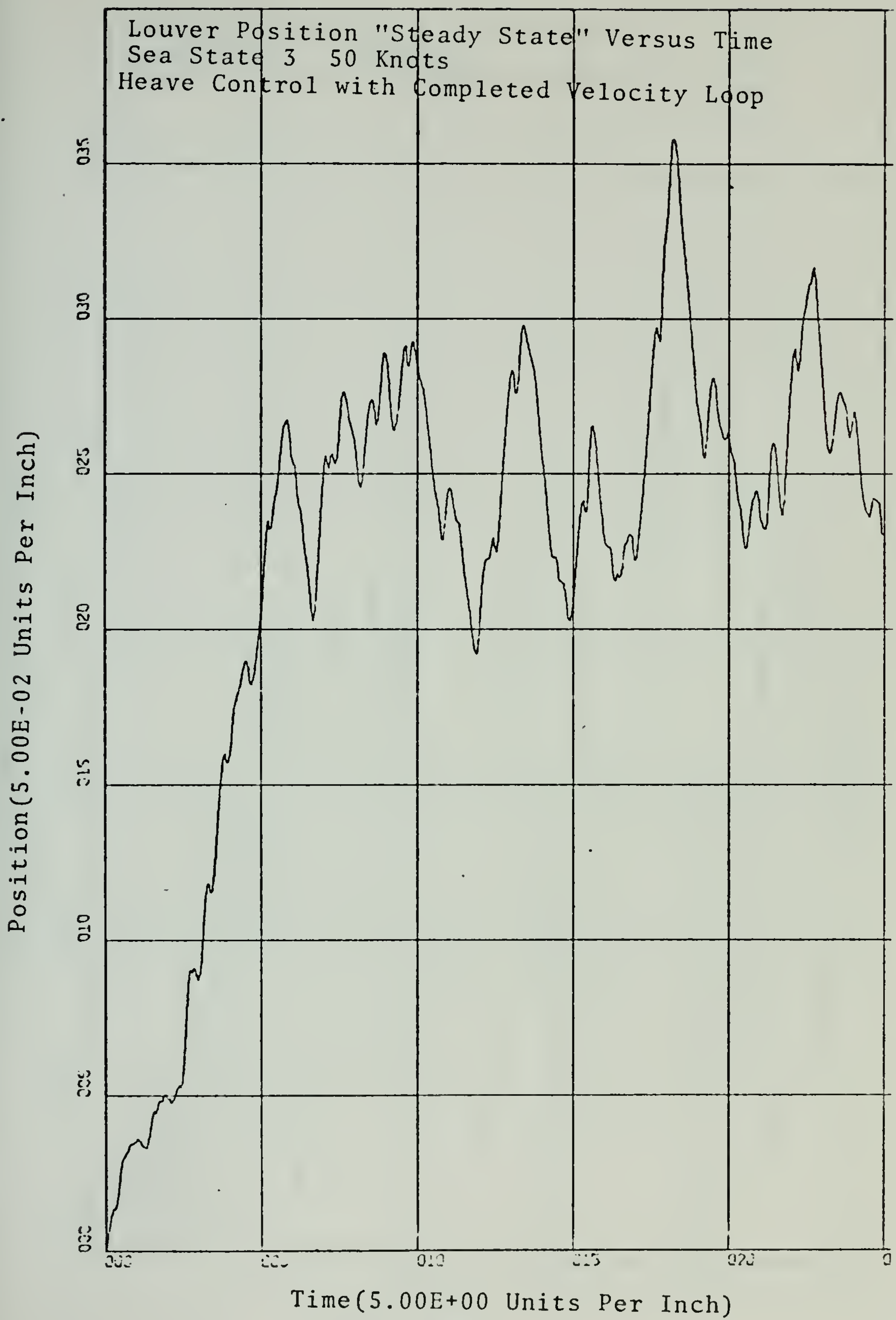

Louver Position "Steady State" Versus Time
Sea State 3 50 Knots
Heave Control with Completed Velocity Loop
Position(5.00E-02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 107.

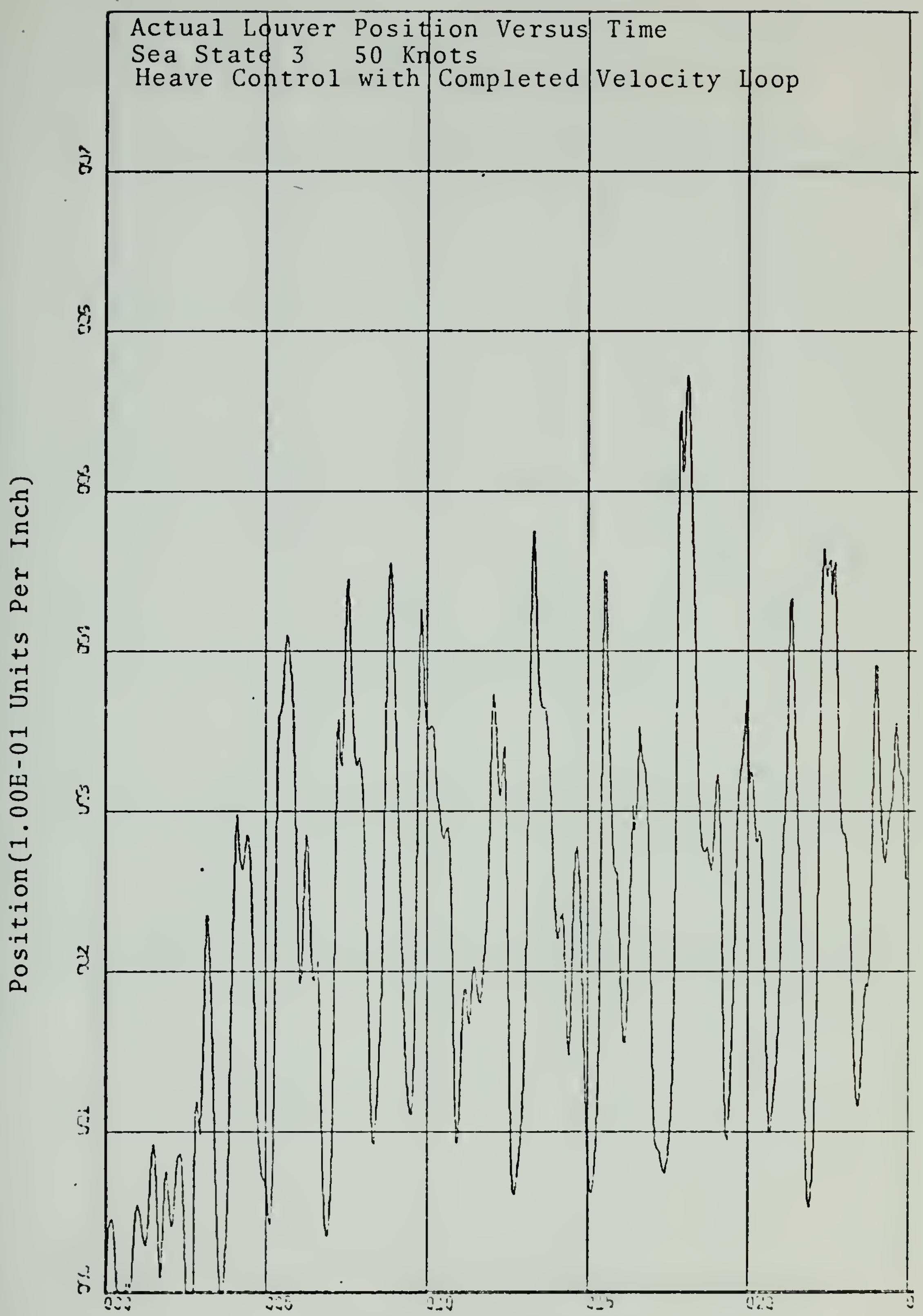

Actual Louver Position Versus Time
Sea State 3 50 Knots
Heave Control with Completed Velocity Loop
Position(1.00E-01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 108.

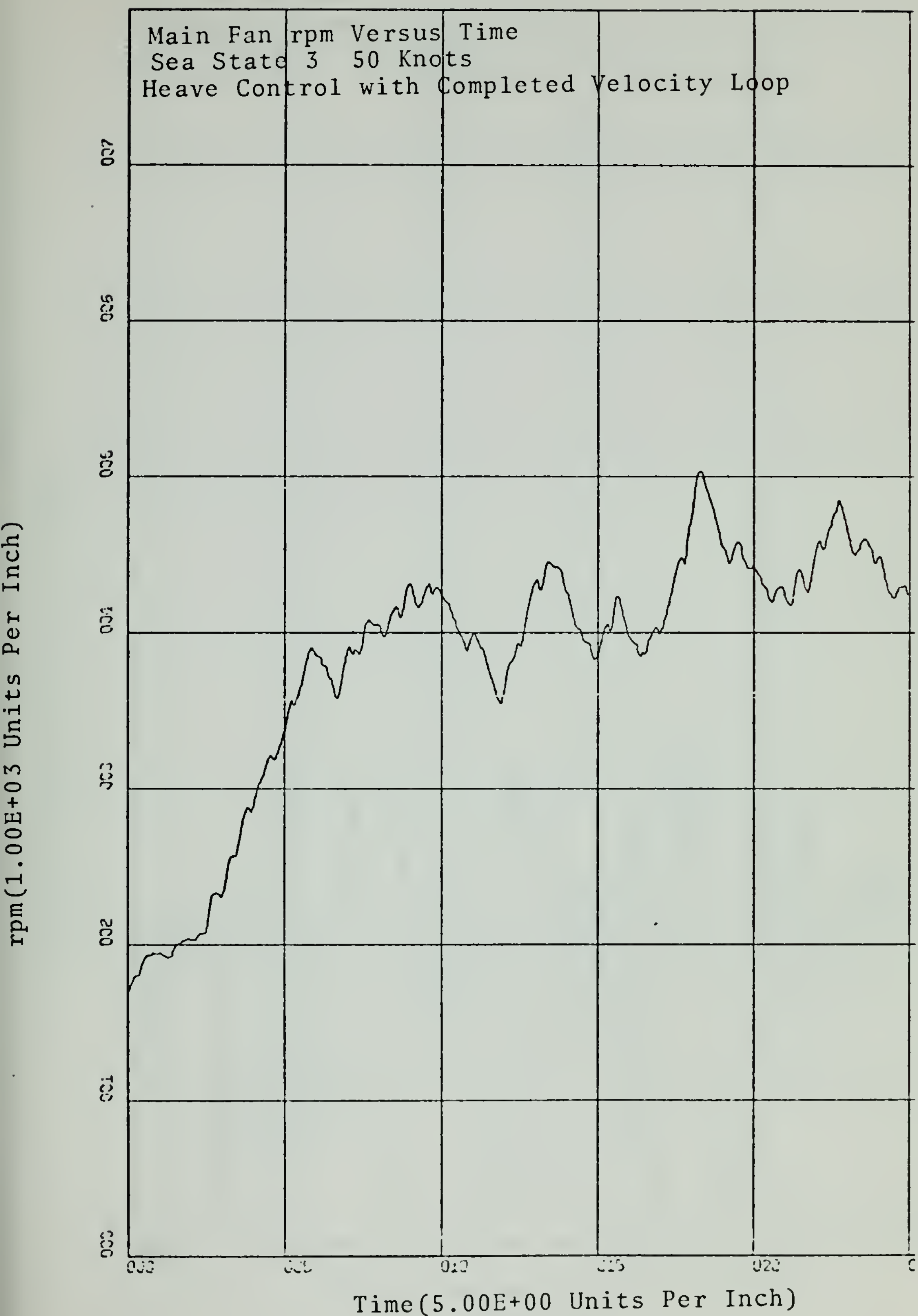

Main Fan rpm Versus Time
Sea State 3 50 Knots
Heave Control with Completed Velocity Loop
rpm(1.00E+03 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 109.

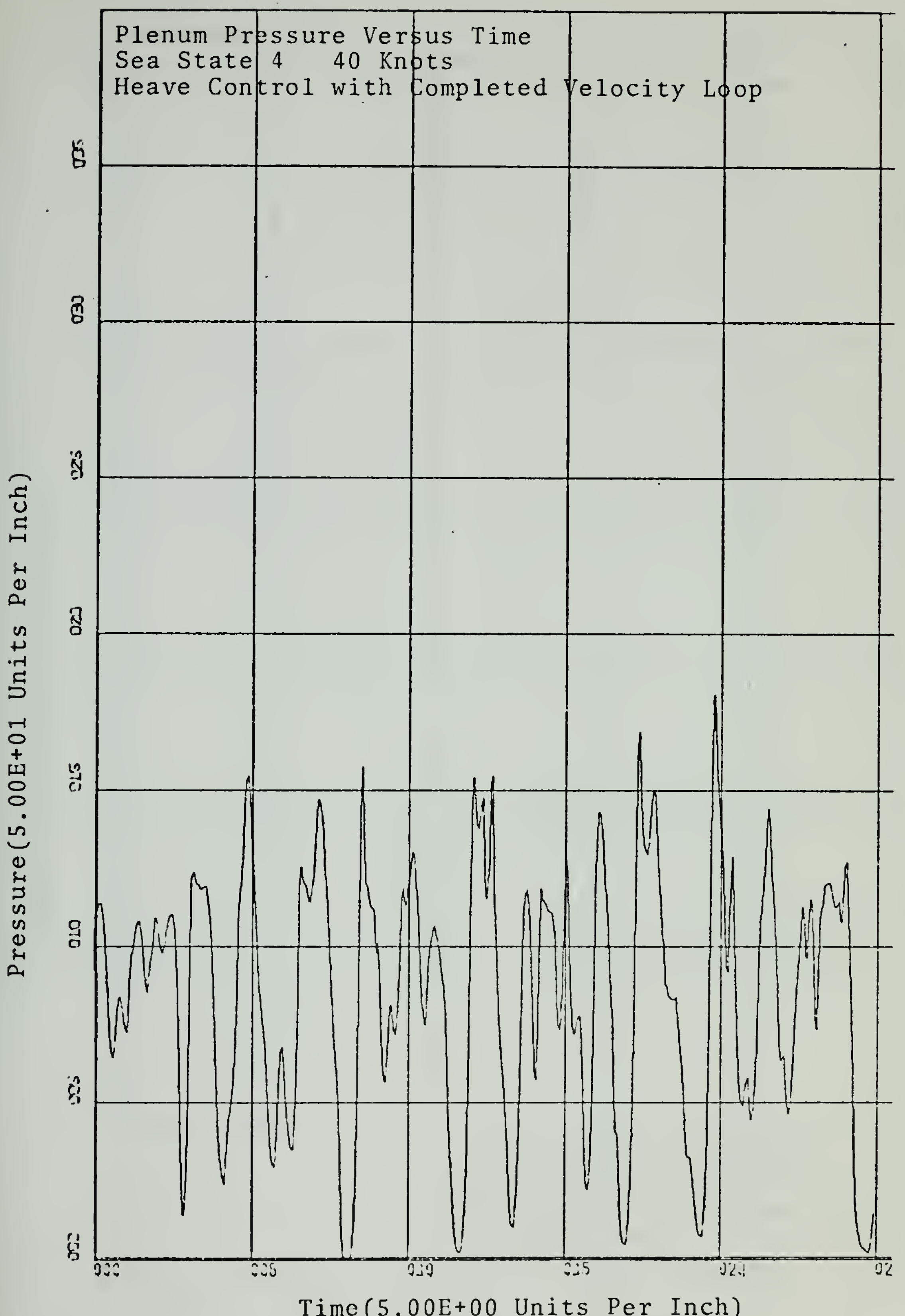

Plenum Pressure Versus Time
Sea State 4 40 Knots
Heave Control with Completed Velocity Loop
Pressure(5.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 110.

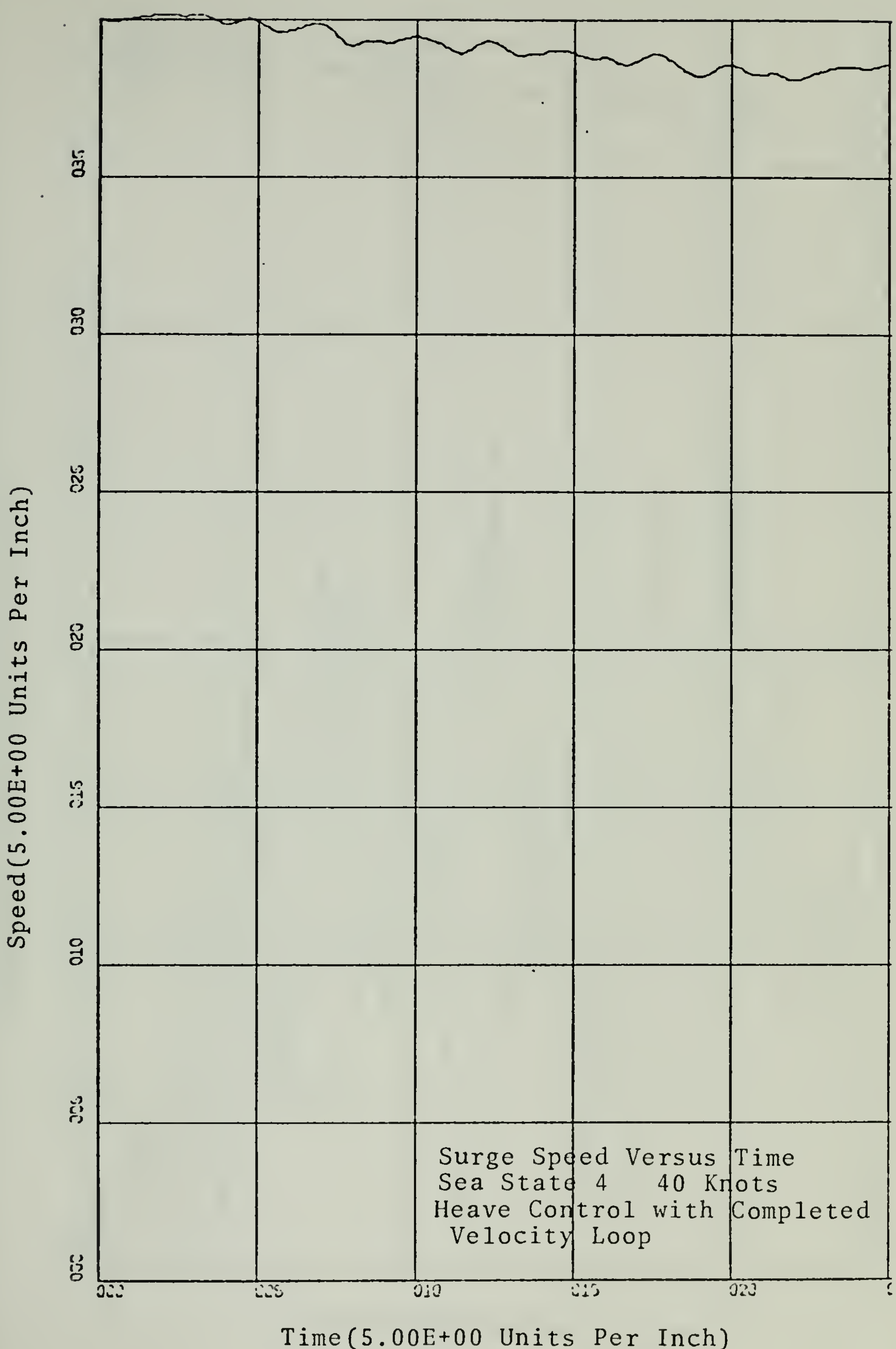
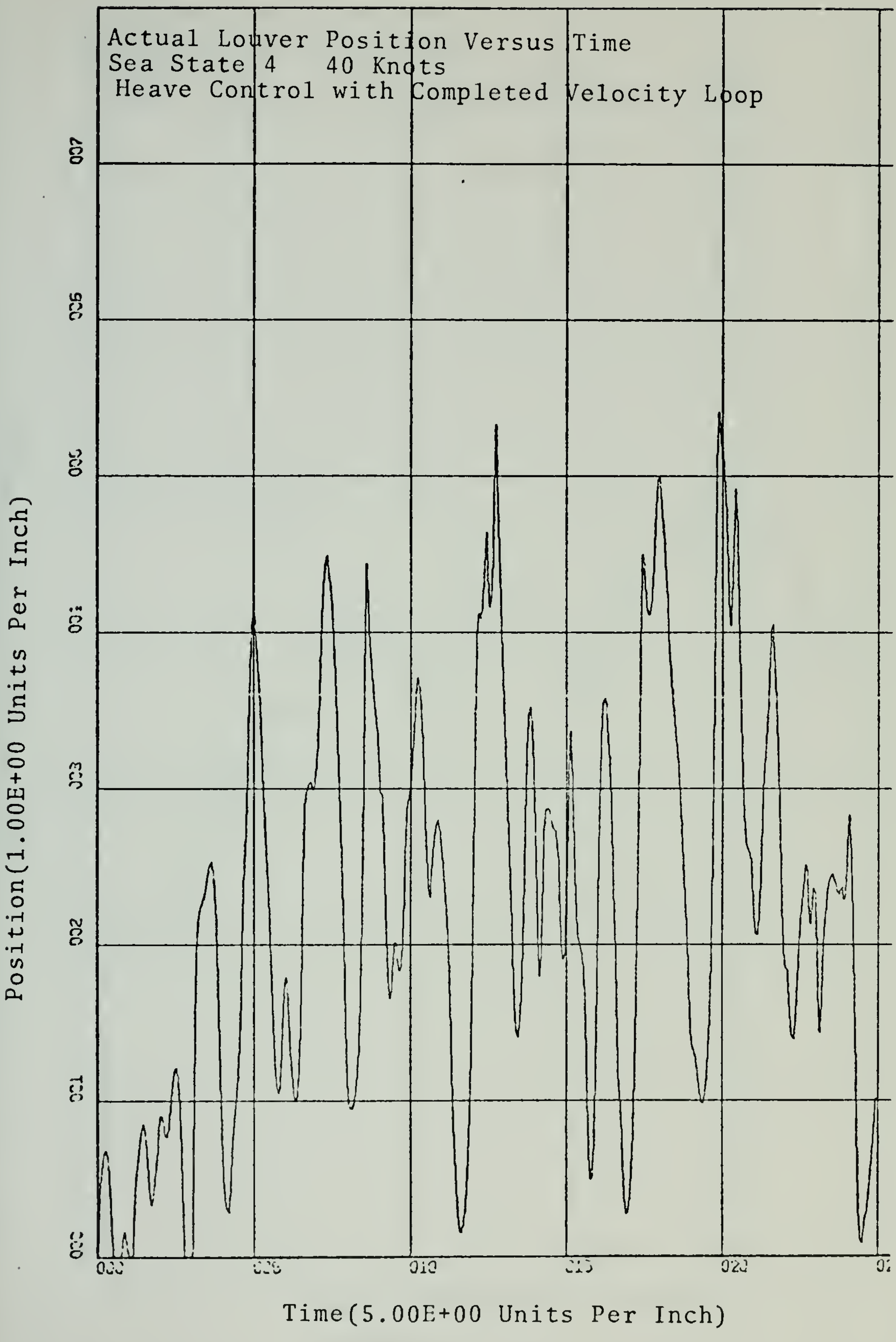

Speed(5.00E+00 Units Per Inch)
Surge Speed Versus Time
Sea State 4   40 Knots
Heave Control with Completed
Velocity Loop
Time(5.00E+00 Units Per Inch)

Figure 111.


Actual Louver Position Versus Time
Sea State 4 40 Knots
Heave Control with Completed Velocity Loop
Position(1.00E+00 Units Per Inch)
Time(5.00E+00 Units Per Inch)
Figure 112.


Main Fan rpm Versus Time
Sea State 4 40 Knots
Heave Control with Completed Velocity Loop
rpm(1.00E+03 Units Per Inch)
Time(5.00E+00 Units Per Inch)
Figure 113.

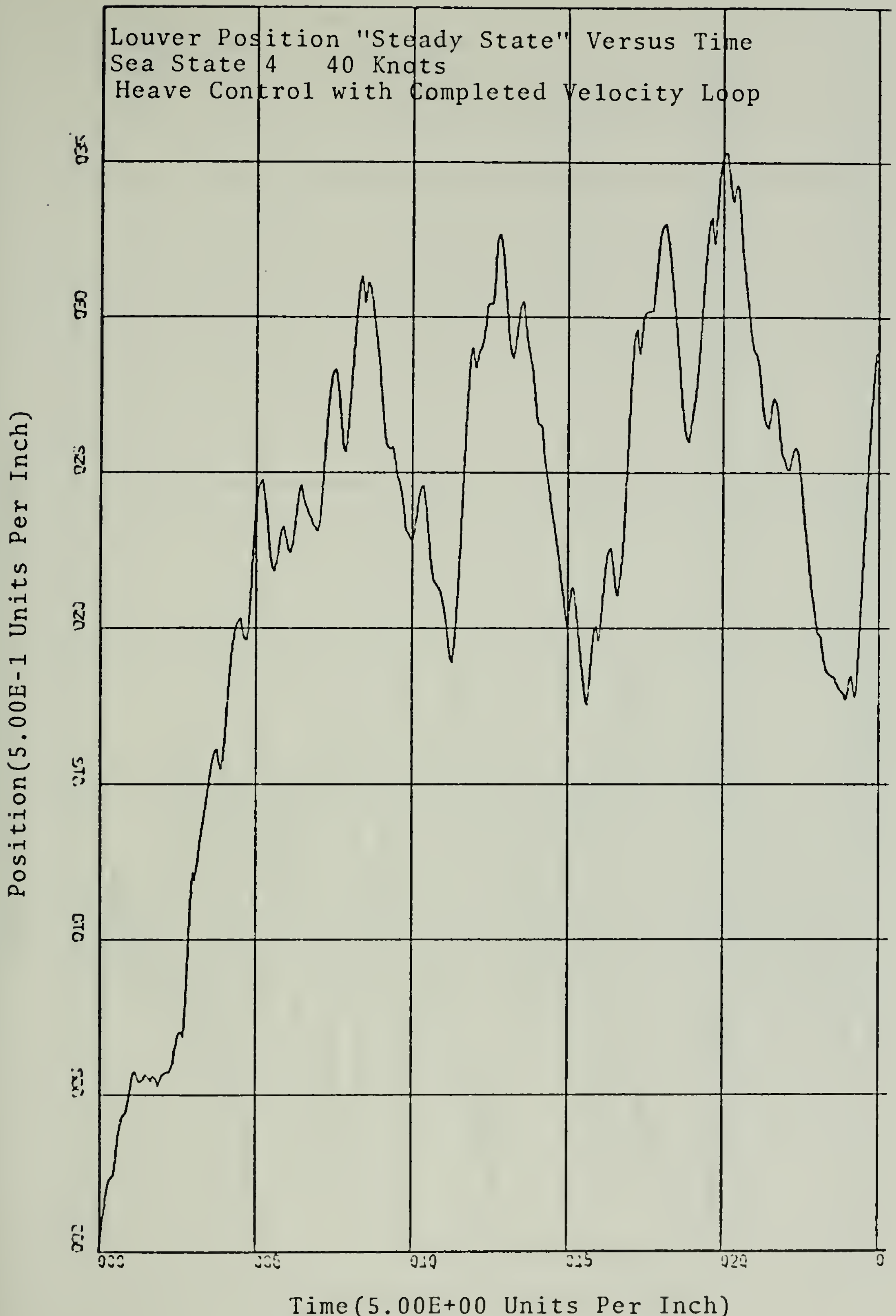

Louver Position "Steady State" Versus Time
Sea State 4 40 Knots
Heave Control with Completed Velocity Loop
Position(5.00E-1 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 114.

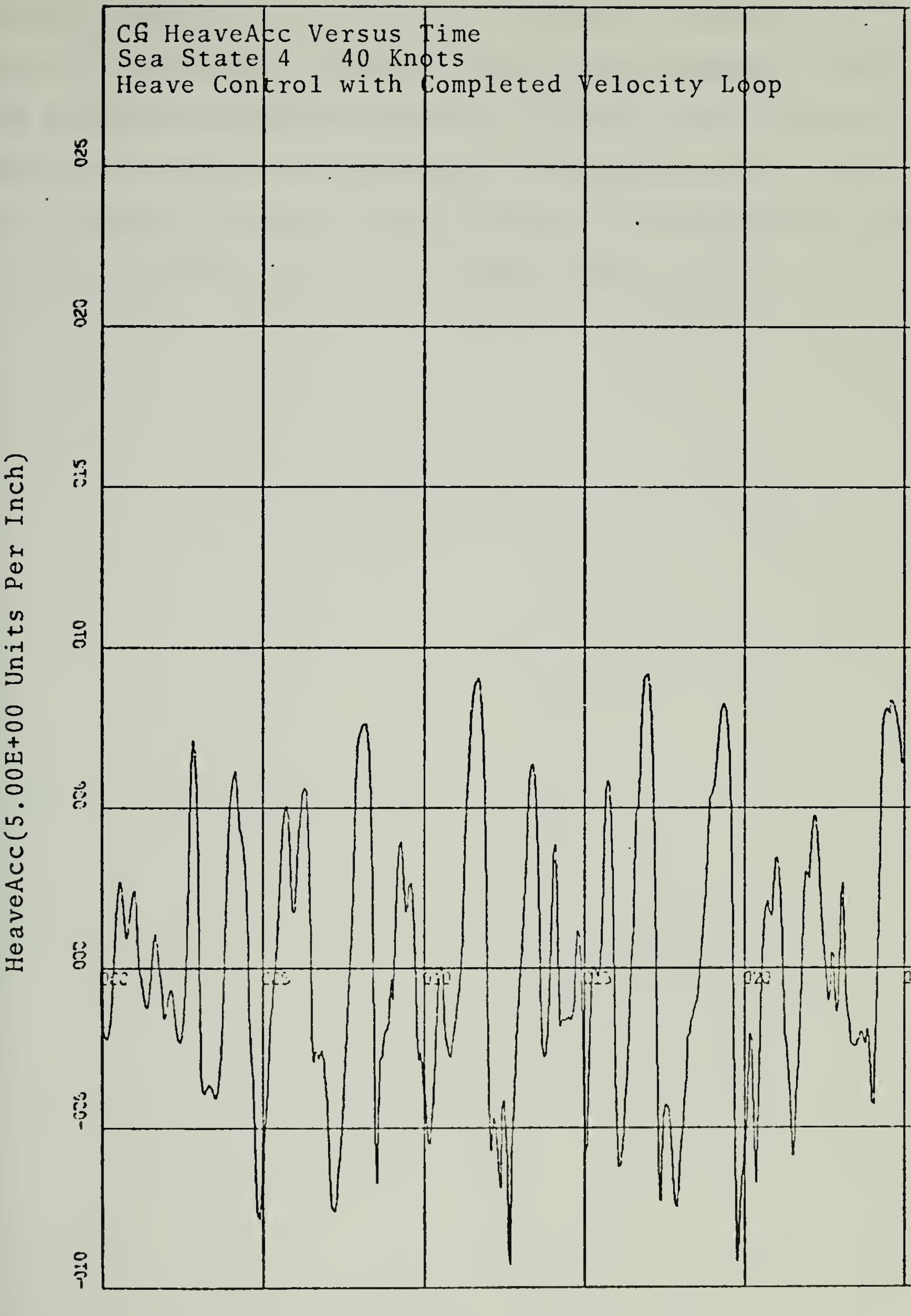

CG HeaveAcc Versus Time
Sea State 4 40 Knots
Heave Control with Completed Velocity Loop
HeaveAcc(5.00E+00 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 115.

was made (Figures 116-121). This run was also made at 50 knots in Sea State 3 and the results, when compared, show the same excellent speed control but with an even larger decrease in heave accelerations. It is important to note also, however, the very great increase in fan rpm which was needed to compensate for the larger venting area.

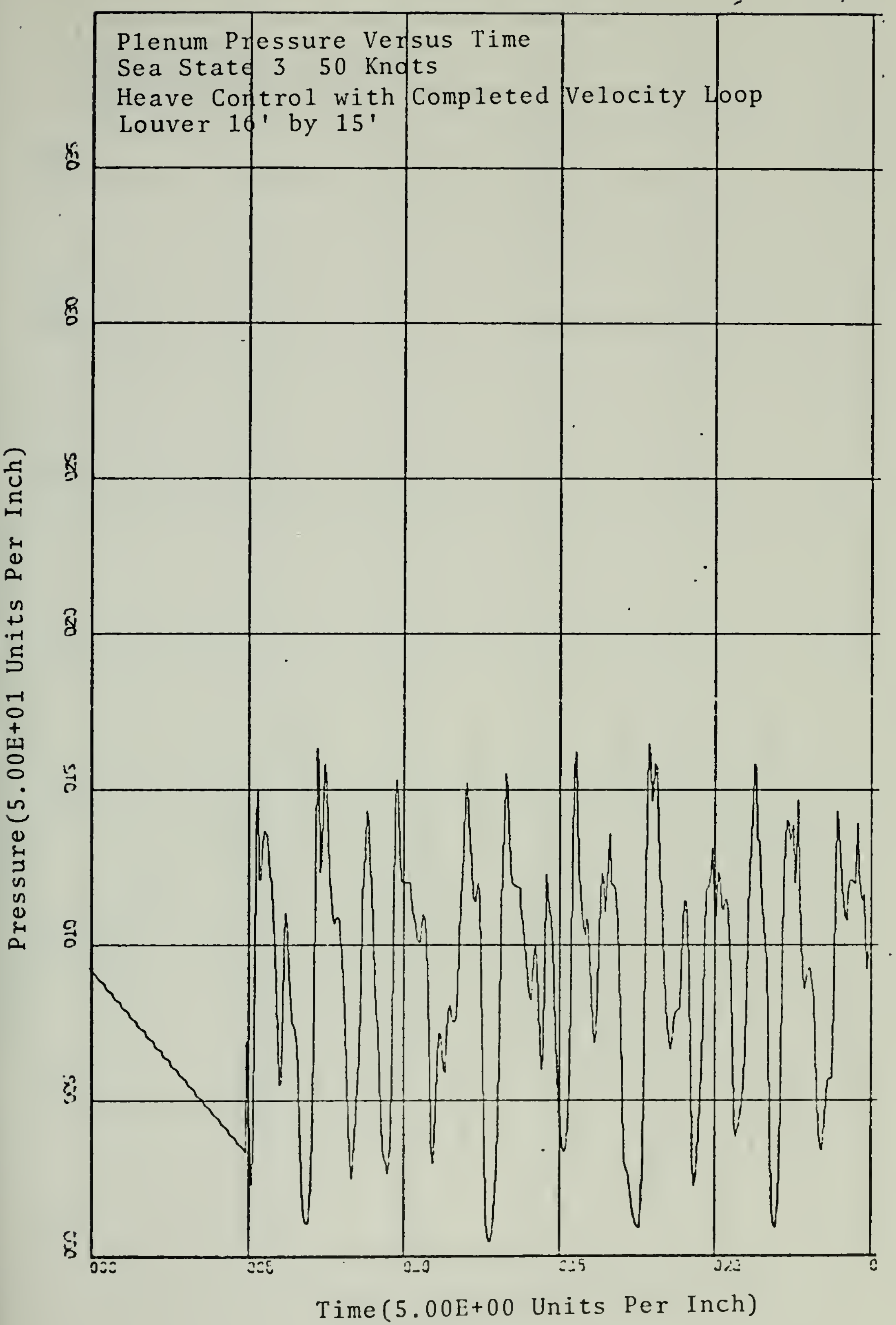

Plenum Pressure Versus Time
Sea State 3 50 Knots
Heave Control with Completed Velocity Loop
Louver 16' by 15'
Pressure(5.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 116.

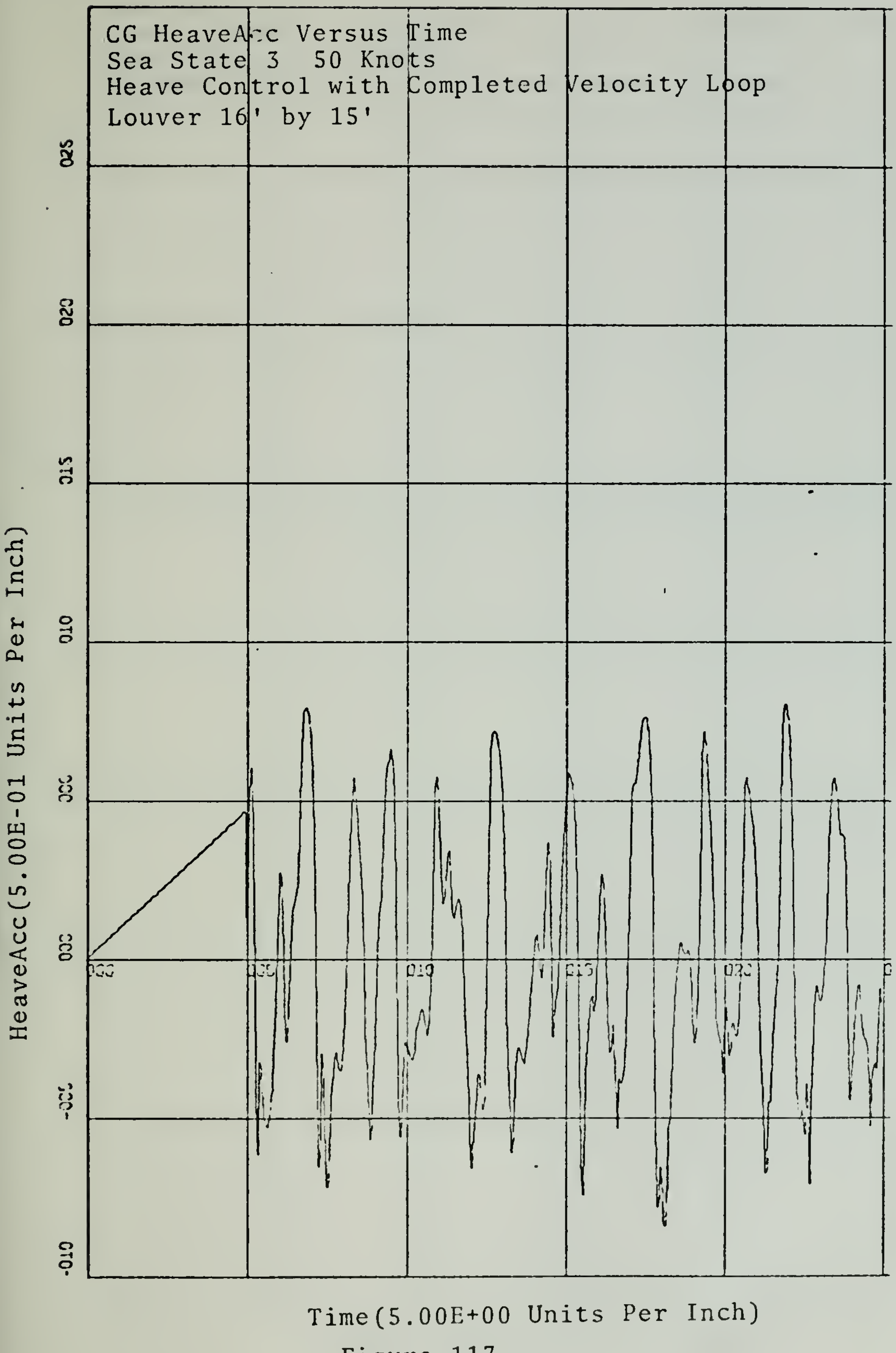

CG HeaveAcc Versus Time
Sea State 3 50 Knots
Heave Control with Completed Velocity Loop
Louver 16' by 15'
HeaveAcc(5.00E-01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 117.

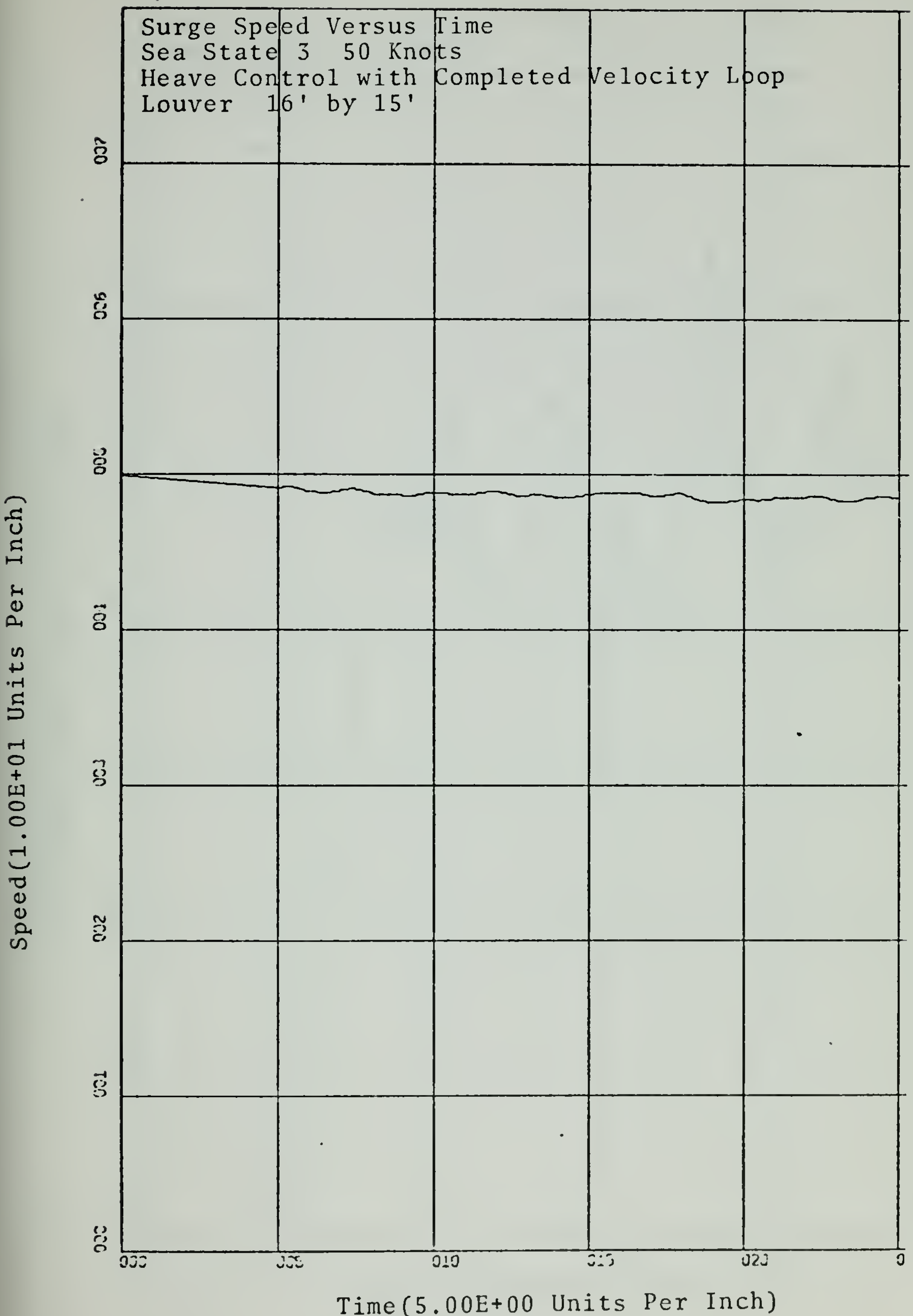
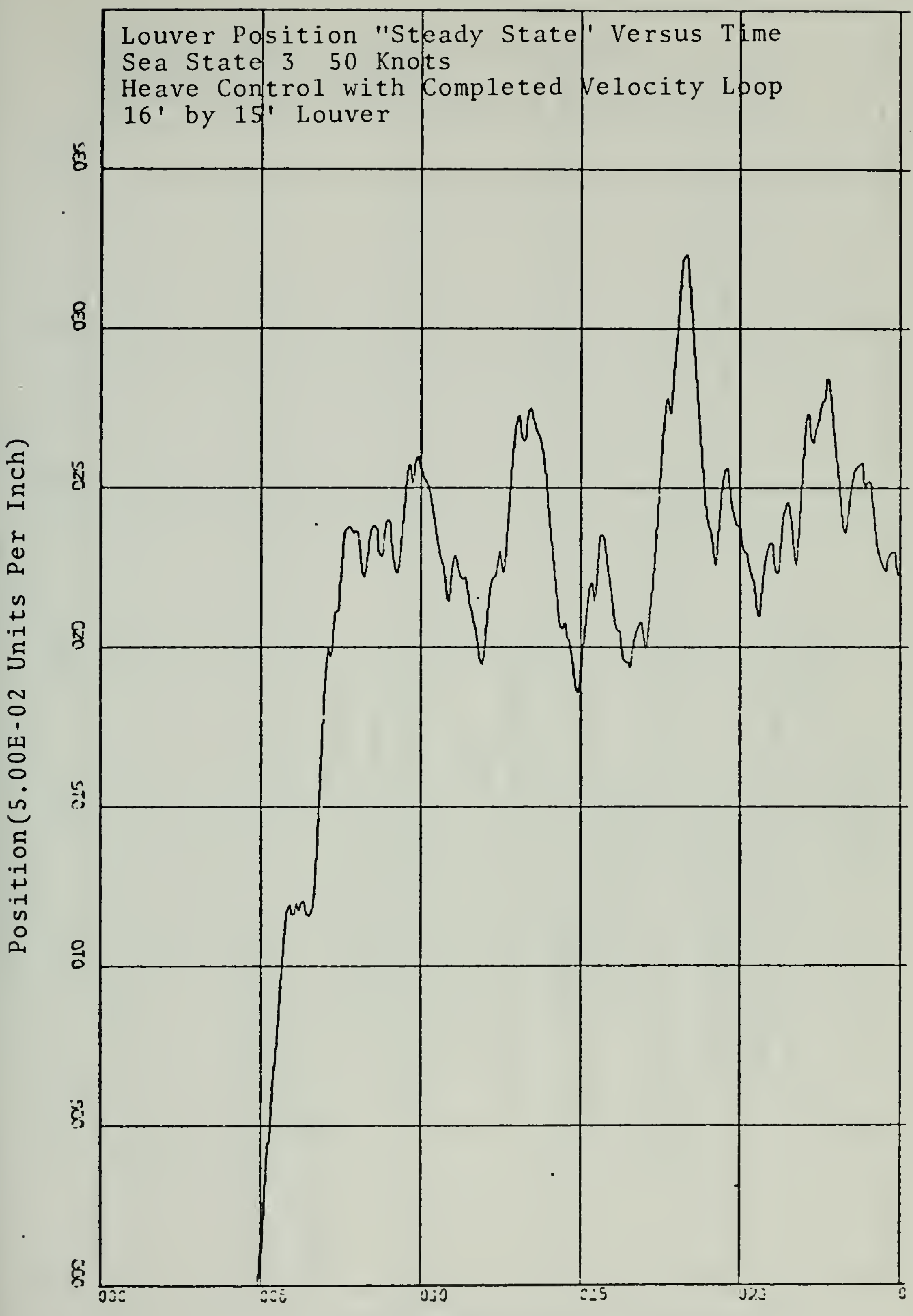

Surge Speed Versus Time
Sea State 3 50 Knots
Heave Control with Completed Velocity Loop
Louver 16' by 15'
Speed(1.00E+01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 118.



Louver Position "Steady State' Versus Time
Sea State 3 50 Knots
Heave Control with Completed Velocity Loop
16' by 15' Louver
Position(5.00E-02 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 119.

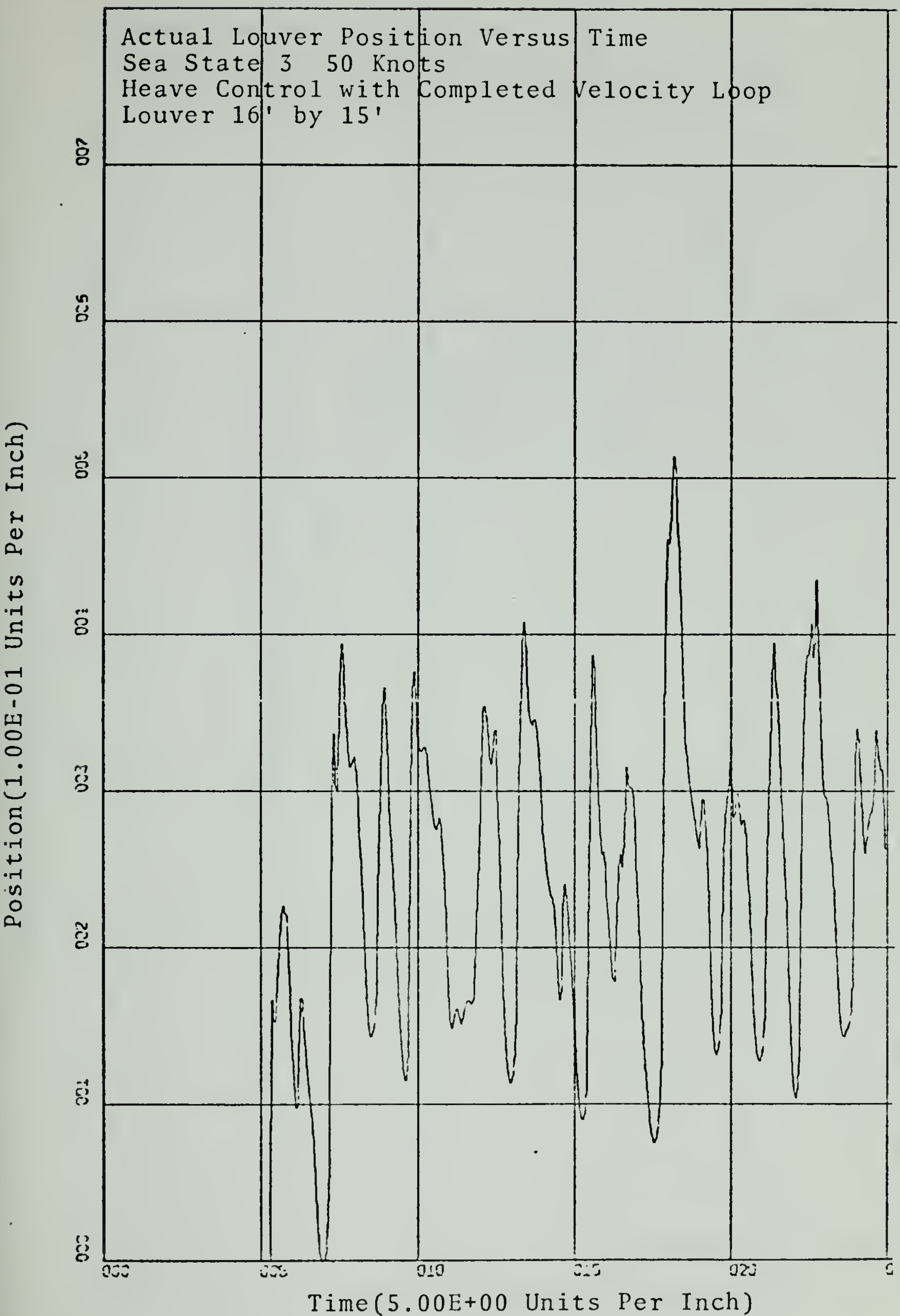
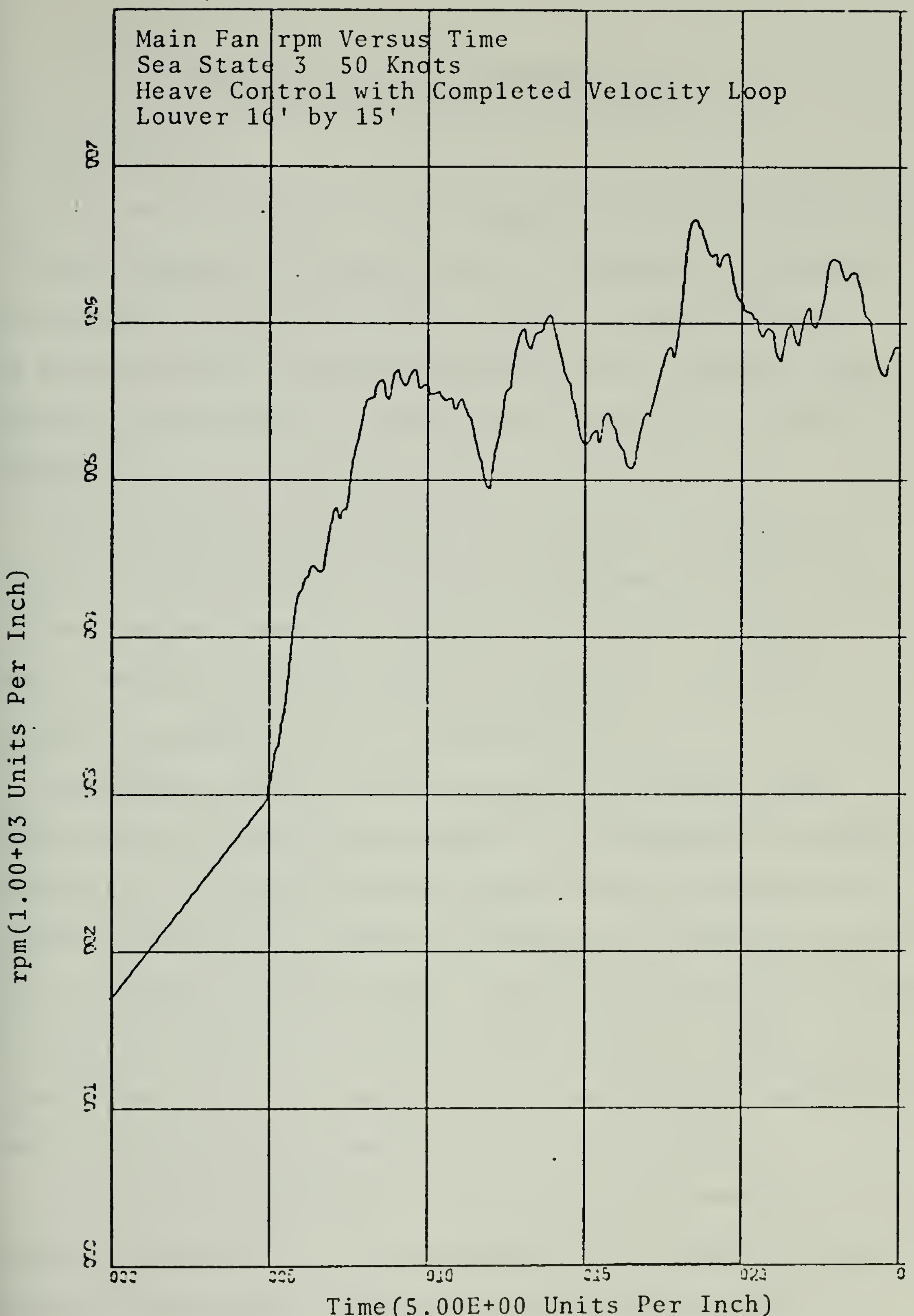

Actual Louver Position Versus Time
Sea State 3 50 Knots
Heave Control with Completed Velocity Loop
Louver 16' by 15'
Position(1.00E-01 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 120.



Main Fan rpm Versus Time
Sea State 3 50 Knots
Heave Control with Completed Velocity Loop
Louver 16' by 15'
rpm(1.00+03 Units Per Inch)
Time(5.00E+00 Units Per Inch)

Figure 121.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The encountering of wave conditions by the SES 100B introduces parameters which result in a decrease in average plenum pressure and a deterioration of forward velocity. It has been shown that restoration of this velocity is possible by insertion of a control loop varying the plenum pressure.

The accuracy of the velocity controller is dependent on both the severity of the wave disturbance and the gain of the feedback loop. Increases in loop gain produced faster response time and greater accuracy, but with increased fluctuations in the plenum pressure.

Insertion of the velocity controller increases the heave accelerations, particularly on the negative or upward direction. By installing the lower system to provide controlled venting and slightly modifying the velocity controller to account for the leakage, heave acceleration is reduced to levels comparable to those before velocity control and significantly below those with just the velocity controller while still providing excellent velocity control.

Main fan rpm and hence total power requirements are greatly increased by the utilization of the louver system. Larger lower leakage area, while giving greater heave acceleration attenuation proportionally created power needs.

B. RECOMMENDATIONS FOR FURTHER STUDY

Several areas of interest could not be explored because of time limitations on the author. Some of these will be listed below as possible items to be studied at some later date.

1. Further Design Studies of the Louver System

a. Introduction of Design Complexities

In the initial modeling of the louver system, certain simplifications and assumptions were made. Nonlinearities and time delays which might exist were ignored. A more comprehensive design study could be undertaken to determine the validity of the initial design.

b. Self-Adaptive Design

It is felt that the louver design as a final physical system should be self-adaptive in nature for optimal performance characteristics. This should make an interesting and rewarding study.

c. Design of Anticipation

The possibility of using the bow acceleration as a form of design anticipation for the louver system has been suggested. A study in which different methods of control anticipation are investigated is recommended.

2. Power Considerations

Power efficiency is essential to the concept of the CAB. A study of the habitability parameters as opposed to power considerations involving the use of a controlled venting system would be useful. Since velocity control can

also be maintained by variations of the thrust, this study could be combined with a comparison of louver versus thrust power tradeoffs for optimal habitability/power analysis.

3. <u>Other Methods of Heave/Velocity Control</u>

Other forms of plenum pressure control should be investigated for use with or in lieu of the controlled venting system.

APPENDIX A: PROGRAMMING OF THE HEAVE/VELOCITY CONTROL

Because of the modular construction of the SES 100-B model, insertion of the heave/velocity control required modification of only the main program and three of the subroutines. All changes and the purpose of these changes will be explained in this appendix. For those unfamilar with the SES 100-B program it is suggested that they refer to references.

1. Changes made to the MAIN program included the addition of two common blocks and the initialization of these blocks to zero. These blocks serve to transfer controller data from INCO to RHS.

2. Since it was felt that the controller should be made as flexible as possible, provision was made for the user to make some changes through data cards. The information is entered in INCON by the use of two data cards which supply the input logic and the information for the controller.

Card	Column	Format		Entry
1	1-5	I	01904 -	Control Tag and Option
	6-15	F		Leakage orifice coefficient
	16-25	F		Width of Louver
	26-35	F		Height of Louver
	36-45	F		Tau one of the Filter
	46-55	F		Constant of the Louver
	56-65	F		Initial Position of Louver
	66-75	F		Control Switch 0.0 - no control 1.0 - heave control only 2.0 - speed control only 3.0 - both controls
2	1-80	20A4		Alphanumeric data to be printed. Can contain any information about the controller.

Changes made to INCON cause this information to be read into the program.

3. Changes made in Subroutine COLFIL enable the user to obtain pertinent data in either printed form or by graphs. Graphs can either be by CALCOMP plotter or from the printer. Provisions were made to output main fan rpm, "steady-state" louver position and actual louver position.

4. The greatest number of changes were made in Subroutine RHS, which contains the FORTRAN expressions for the right-hand side of the system of first order differential equations required for the model simulation. The logic for the heave and velocity control was placed in Subroutine RHS.

A complete listing of the SES 100-B program with changes follows.

THE PROGRAM WHICH FOLLOWS IS A FORTRAN SIMULATION MODEL OF THE BELL-100B, A SURFACE EFFECT SHIP. THE ORIGINAL PROGRAM BY OCEANICS, INC HAS BEEN MODIFIED TO PROVIDE HEAVE/VELOCITY CONTROL BY VARIATIONS OF THE PLENUM PRESSURE THROUGH A LOUVER SYSTEM FOR CONTROLLED VENTING AND MAIN FAN RPM CHANGES.

```
C     MAIN PROGRAM
      INTEGER ON
      COMMON /AIR/ PINF,RHOINF,GAM
      COMMON /BMCO/ IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IY
      COMMON /CONST/ PI,RAD,UO
      COMMON /EQNCO/ NEQS,TOL(20),JQQ
      COMMON /ENGINE/ TOUT,THRUST,THRSTO,STHRST,XP,YP,ZP
      COMMON /FPROP/ FXP,FYP,FZP,FKP,FMP,FNP
      COMMON /FROUDE/ FN,FNCRIT
      COMMON /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,I
     1RUD,IPROP,IAEROD,IRHS
      COMMON /ROLL/ PHIMAX,TROLL
      COMMON /RUDDR/ DELRUD,RUDON,RUDOFF,RUDRAT,COSRUD,XR,YR,ZR,TANRUD,R
     1UDREV,IRDS,TL,RSPAN,RAREA,RASPR,RCLB,RTC,RUDMAX,RRDRAT,RRDMAX
      COMMON /VALOLD/ YOLD(20)
      COMMON /VARBLE/ VAL(40)
      COMMON /WAVE/ ETA(4,11),AW(10),OMEGA(10),DVOLW,NWAVE,BETA,FXWAV,FY
     1WAV,FZWAV,FKWAV,FMWAV,FNWAV,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PB
     2BAR
      EQUIVALENCE (VAL(2),U), (VAL(3),V), (VAL(4),W), (VAL(5),P), (VAL(6
     1),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VAL(10),Z), (VAL(
     211),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI), (VAL(24),PB)
      DIMENSION DUMMY(20)
      TC = 1.0
      ON = 1
      PI = 4.*ATAN(1.)
      RAD = 180./PI
      WRITE (6,12)
    1 READ (44,13,END=2) DUMMY
      WRITE (6,14) DUMMY
      WRITE (5,13) DUMMY
      GO TO 1
    2 REWIND 5
    3 CALL INCON (TIME)
      IF (IMM.EQ.3) GO TO 11
C
      DO 4 J=1,20
    4 YOLD(J) = VAL(J+1)
C
```

```
      GO TO 8
    5 CONTINUE
      TOLD = TIME
      PBBAR = PBBAR*(1.-DELT/TC)+DELT*(PB-PINF)/TC
      IF (NWAVE.LE.0) GO TO 6
      ZBAR = (1.-DELT/TC)*ZBAR+DELT*Z/TC
      PHIBAR = (1.-DELT/TC)*PHIBAR+DELT*PHI/TC
      THEBAR = (1.-DELT/TC)*THEBAR+DELT*THETA/TC
      CALL WAVES (TIME)
    6 CALL SIDEWL
      CALL PROP
      CALL RUDDER
      CALL AEROD
      CALL INTGRL (TIME)
      IF (TIME.GT.FTIME) GO TO 10
      IF (FN.GT.FNCRIT) GO TO 7
      PRINT 17
      GO TO 10
    7 DELOLD = TIME-TOLD
      PSI = PSI+DELOLD*R
      X = X+DELOLD*(U*COS(PSI)-V*SIN(PSI))
      Y = Y+DELOLD*(U*SIN(PSI)+V*COS(PSI))
      IF (ABS(TIME-TPRINT).LT.1.E-6) GO TO 8
      GO TO 5
    8 CONTINUE
      IF (ITRAJ.EQ.0) GO TO 9
      DPHI = PHI*RAD
      DPSI = PSI*RAD
      DTHETA = THETA*RAD
      DP = P*RAD
      DQ = Q*RAD
      DR = R*RAD
      WRITE (6,15) TIME,U,V,W,DP,DQ,DR,Z,DPHI,DTHETA,X,Y,DPSI
      BETS = (-V/U)*RAD
      DELRS = DELRUD*RAD
      WRITE (6,16) BETS,DELRS,FXP
    9 CONTINUE
      IMMTAG = (IMM+1)/2
      IF (IMMTAG.EQ.1.AND.TIME.GE.BTIME-1.E-8) IMT=1
      TPRINT = TPRINT+DELPNT
      ON = 1
      GO TO 5
   10 CALL COLFIL
      IF (IMM.LT.1) GO TO 3
      IF (IMM.NE.1) GO TO 11
      END FILE IBMFIL
      GO TO 3
   11 CALL SAM
```

```
      GO TO 3                                                           MAIN 880
C                                                                       MAIN 890
   12 FORMAT (1H1//35X,22H LISTING OF INPUT DECK//)                     MAIN 900
   13 FORMAT (20A4)                                                     MAIN 910
   14 FORMAT (5X,20A4)                                                  MAIN 920
   15 FORMAT (//10X,13HTIME (SEC) = F6.2//10X,33HTRANSLATIONAL VELOCITIEMAIN 930
     1S (FT/SEC)/10X,2HU=F6.2,5X,2HV=F6.2,5X,2HW=F6.3//10X,31HROTATIONALMAIN 940
     2 VELOCITIES (DEG/SEC)/10X,2HP=F6.2,5X,2HQ=F6.2,5X,2HR=F6.2//10X,30MAIN 950
     3HDISPLACEMENTS (FT AND DEGREES)/10X,2HZ=F7.3,5X,4HPHI=F6.2,3X,6HTHMAIN 960
     4ETA=F6.2//10X,27HTRAJECTORY (FT AND DEGREES)/10X,2HX=F8.2,4X,2HY=FMAIN 970
     58.2,4X,4HPSI=F8.2)                                                MAIN 980
   16 FORMAT (1H0,9X,23HSIDESLIP ANGLE (DEG) = F8.2,10X,21HRUDDER ANGLE MAIN 990
     1(DEG) = F8.3,10X,15HTHRUST (LBS) = F12.1)                         MAIN1000
   17 FORMAT (///25X,28HCRAFT SPEED BELOW HUMP SPEED)                   MAIN1010
      END                                                               MAIN1020
```

```
C
      BLOCK DATA                                                        BKDT  10
      COMMON /AIR/ Z1(3)                                                BKDT  20
      COMMON /BMCO/ Z2(25)                                              BKDT  30
      COMMON /COLUMN/ Z3(2)                                             BKDT  40
      COMMON /CONST/ Z4(3)                                              BKDT  50
      COMMON /CNTRL/ Z5(10)                                             BKDT  60
      COMMON /ENGINE/ Z6(7)                                             BKDT  70
      COMMON /EQNCO/ Z7(22)                                             BKDT  80
      COMMON /FAERO/ Z8(6)                                              BKDT  90
      COMMON /FAIR/ Z9(2)                                               BKDT 100
      COMMON /FANMAP/ Z10(160)                                          BKDT 110
      COMMON /FORBS/ Z11(7)                                             BKDT 120
      COMMON /FORSS/ Z12(8)                                             BKDT 130
      COMMON /FPROP/ Z13(6)                                             BKDT 140
      COMMON /FROUDE/ Z14(2)                                            BKDT 150
      COMMON /FRUD/ Z15(6)                                              BKDT 160
      COMMON /GBOW/ Z16(1)                                              BKDT 170
      COMMON /GEOM/ Z17(138)                                            BKDT 180
      COMMON /GEOMBS/ Z18(62)                                           BKDT 190
      COMMON /GEOMSS/ Z19(62)                                           BKDT 200
      COMMON /GEOMSW/ Z20(11)                                           BKDT 210
      COMMON /KSWTCH/ Z21(1)                                            BKDT 220
      COMMON /LEAKER/ Z22(2)                                            BKDT 230
      COMMON /MASSES/ Z23(817)                                          BKDT 240
      COMMON /MATRIX/ Z24(36)                                           BKDT 250
      COMMON /MSIDW/ Z25(55)                                            BKDT 260
      COMMON /MWAVE/ Z26(12)                                            BKDT 270
      COMMON /OPTION/ Z27(3)                                            BKDT 280
      COMMON /PLENUM/ Z28(4)                                            BKDT 290
      COMMON /PLVCQQ/ Z28A(4)                                           BKDT 300
      COMMON /PRIME/ Z29(5)                                             BKDT 310
      COMMON /PRTINT/ Z30(12)                                           BKDT 320
      COMMON /PWAVE/ Z31(2)                                             BKDT 330
      COMMON /RISER/ Z32(1)                                             BKDT 340
      COMMON /ROLL/ Z33(2)                                              BKDT 350
      COMMON /RUDDR/ Z34(20)                                            BKDT 360
      COMMON /SIDE/ Z35(22)                                             BKDT 370
      COMMON /SOFTBS/ Z36(25)                                           BKDT 380
      COMMON /SOFTSS/ Z37(19)                                           BKDT 390
      COMMON /STABLE/ Z38(5)                                            BKDT 400
      COMMON /STSLR/ Z39(2)                                             BKDT 410
      COMMON /VALOLD/ Z40(20)                                           BKDT 420
      COMMON /VARBLE/ Z41(40)                                           BKDT 430
      COMMON /VCONTL/ Z45(3)                                            BKDT 440
      COMMON /VLUVER/ Z44(5)                                            BKDT 450
      COMMON /WAVE/ Z42(80)                                             BKDT 460
      COMMON /WAVEF/ Z43(40)                                            BKDT 470
```

```
      DATA Z1/3*0.0/                                                    BKDT 480
      DATA Z2/25*0.0/                                                   BKDT 490
      DATA Z3/2*0.0/                                                    BKDT 500
      DATA Z4/3*0.0/                                                    BKDT 510
      DATA Z5/10*0.0/                                                   BKDT 520
      DATA Z6/7*0.0/                                                    BKDT 530
      DATA Z7/22*0.0/                                                   BKDT 540
      DATA Z8/6*0.0/                                                    BKDT 550
      DATA Z9/2*0.0/                                                    BKDT 560
      DATA Z10/160*0.0/                                                 BKDT 570
      DATA Z11/7*0.0/                                                   BKDT 580
      DATA Z12/8*0.0/                                                   BKDT 590
      DATA Z13/6*0.0/                                                   BKDT 600
      DATA Z14/2*0.0/                                                   BKDT 610
      DATA Z15/6*0.0/                                                   BKDT 620
      DATA Z16/0.0/                                                     BKDT 630
      DATA Z17/138*0.0/                                                 BKDT 640
      DATA Z18/62*0.0/                                                  BKDT 650
      DATA Z19/62*0.0/                                                  BKDT 660
      DATA Z20/11*0.0/                                                  BKDT 670
      DATA Z21/0.0/                                                     BKDT 680
      DATA Z22/2*0.0/                                                   BKDT 690
      DATA Z23/817*0.0/                                                 BKDT 700
      DATA Z24/36*0.0/                                                  BKDT 710
      DATA Z25/55*0.0/                                                  BKDT 720
      DATA Z26/12*0.0/                                                  BKDT 730
      DATA Z27/3*0.0/                                                   BKDT 740
      DATA Z28/4*0.0/                                                   BKDT 750
      DATA Z28A/4*0.0/                                                  BKDT 760
      DATA Z29/5*0.0/                                                   BKDT 770
      DATA Z30/12*0.0/                                                  BKDT 780
      DATA Z31/2*0.0/                                                   BKDT 790
      DATA Z32/0.0/                                                     BKDT 800
      DATA Z33/2*0.0/                                                   BKDT 810
      DATA Z34/20*0.0/                                                  BKDT 820
      DATA Z35/22*0.0/                                                  BKDT 830
      DATA Z36/25*0.0/                                                  BKDT 840
      DATA Z37/19*0.0/                                                  BKDT 850
      DATA Z38/5*0.0/                                                   BKDT 860
      DATA Z39/2*0.0/                                                   BKDT 870
      DATA Z40/20*0.0/                                                  BKDT 880
      DATA Z41/40*0.0/                                                  BKDT 890
      DATA Z42/80*0.0/                                                  BKDT 900
      DATA Z43/40*0.0/                                                  BKDT 910
      DATA Z44/5*0.0/                                                   BKDT 920
      DATA Z45/3*0.0/                                                   BKDT 930
      END                                                               BKDT 940
```

```
C
      SUBROUTINE AEROD
      INTEGER ON
      COMMON /FAERO/ FX,FY,FZ,FK,FM,FN
      COMMON /FAIR/ RHOA,XLAERO
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,I
     1RUD,IPROP,IAEROD,IRHS
      COMMON /VARBLE/ VAL(40)
      EQUIVALENCE (VAL(2),U), (VAL(3),V), (VAL(4),W), (VAL(5),P), (VAL(6
     1),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VAL(10),Z), (VAL(
     211),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI), (VAL(24),PB)
      QA = RHOA*U*U
      QAL = QA*XLAERO
      BETA = -V/U
      BETASQ = BETA*BETA
      FX = -(.71812*BETASQ+.063)*QA
      FY = (.82073*BETASQ+.45837*BETA)*QA
      FZ = -(.20517*BETASQ+0.210)*QA
      FK = 0.0
      FM = .022*QAL
      FN = (-.61551*BETASQ+.32945*BETA)*QAL
      IF (IAEROD.NE.ON) RETURN
      WRITE (6,1) FX,FY,FZ,FK,FM,FN
      RETURN
C
    1 FORMAT (/10X,23HAEROD FX,FY,FZ,FK,FM,FN/6E15.4)
      END
```

```
C
      SUBROUTINE BOWSL
      INTEGER ON
      COMMON /AIR/ PINF,RHOINF,GAM
      COMMON /CONST/ PI,RAD,UO
      COMMON /FORBS/ FX,FY,FZ,FK,FM,FN,QL
      COMMON /GEOM/ WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM,DELS(4,
     110),XCP,ZCP
      COMMON /GEOMBS/ DETABX(11),DETABT(11),ARM1B(10),ARM2B(10),DFBS(10)
     1,TSKIB(10)
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AM
     1I(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,I
     1RUD,IPROP,IAEROD,IRHS
      COMMON /SOFTBS/ DSBS,CFBS,PBS,DPBS,YAVGB(10),DELYBS(10),ELMAXB
      COMMON /VARBLE/ VAL(40)
      COMMON /WAVE/ ETA(4,11),AW(10),OMEGA(10),DVOLW,NWAVE,BETA,FXWAV,FY
     1WAV,FZWAV,FKWAV,FMWAV,FNWAV,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PB
     2BAR
      DIMENSION GAP(11), ELSKI(11)
      DIMENSION ATAB(6), ZTAB(6)
      DATA NPTS,IBS/6,0/
      DATA ATAB/0.0,.9375,1.6389,2.1514,2.5,2.8864/
      DATA ZTAB/3.75,4.00,4.42,4.83,5.25,5.67/
      DATA SINBS/.7716/
      EQUIVALENCE (VAL(1),TIME), (VAL(2),U), (VAL(3),V), (VAL(4),W), (VA
     1L(5),P), (VAL(6),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VA
     2L(10),Z), (VAL(11),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI)
     3, (VAL(24),PB)
      DATA ENU/1.28E-5/
C
      DO 1 J=1,11
      GAP(J) = 0.0
      ELSKI(J) = 0.0
    1 CONTINUE
C
      FX = 0.0
      FZ = 0.0
      FK = 0.0
      FM = 0.0
      FN = 0.0
      ALBS = 0.0
      PBAR = PB-PINF
      DELP = PBAR
      IF (DELP.LT.0.0) DELP=0.0
      N = NSTA(3)
C
      DO 2 K=1,N
```

```
      GAP(K) = -(Z+ZS-XX(3,K)*THETA+YY(3,K)*PHI+ETA(3,K))
      ELSKI(K) = -GAP(K)
      IF (GAP(K).LT.0.0) GAP(K)=0.0
    2 CONTINUE
C
      N = N-1
C
      DO 6 K=1,N
      ELSKIA = (ELSKI(K+1)+ELSKI(K))/2.
      IF (ELSKIA.LE.0.0) GO TO 4
      DFBS(K) = 0.0
      IF (ELSKIA.LT.ELMAXB) GO TO 3
      SECARE = FGI(ELSKIA,NPTS,ZTAB,ATAB,IBS)
      DFBS(K) = -DSBS*SECARE*RHO*G
      ELSKIA = ELMAXB
    3 CONTINUE
      ARM1B(K) = XX(3,K)+ELSKIA/2.*DELYBS(K)/DSBS
      ARM2B(K) = ZS-ELSKIA
      DFBS(K) = -DELP*ELSKIA*DSBS/SINBS+DFBS(K)
      ARG = .5*RHO*U*U*ELSKIA*DSBS
      RESKI = U*ELSKIA/ENU*DSBS/DELYBS(K)
      CDTSKI = .427/(ALOG10(RESKI)-.407)**2.64
      TSKIB(K) = -ARG*CDTSKI
      GO TO 5
    4 DFBS(K) = 0.0
      TSKIB(K) = 0.0
    5 CONTINUE
      FX = FX+TSKIB(K)
      FZ = FZ+DFBS(K)
      FK = FK+DFBS(K)*YAVGB(K)
      FM = FM-DFBS(K)*ARM1B(K)+TSKIB(K)*ARM2B(K)
      FN = FN-TSKIB(K)*YAVGB(K)
      ALBS = ALBS+(GAP(K)+GAP(K+1))/2.*DSBS
    6 CONTINUE
C
      QL = CFBS*ALBS*SQRT(2.*ABS(PBAR)/RHOINF)*SIGN(1.,PBAR)
      IF (VAL(1).EQ.0.0) THEQL=THETA
      FM = FM+(THETA-THEQL)*(-3.16E6-1029.8*U*U)
      IF (IBOWSL.NE.ON) RETURN
      WRITE (6,7) GAP,ELSKI,FX,FY,FZ,FK,FM,FN
      RETURN
C
    7 FORMAT (//10X,8HBOW SEAL/26H GAP (FT.) (PORT TO STBD.)/11F10.5/28H
     1 ELSKI (FT.) (PORT TO STBD.)/11F10.5/10X,23HBOWSL FX,FY,FZ,FK,FM,F
     2N/6E15.4)
      END
```

```
C
      SUBROUTINE COLFIL                                                 COLF0010
C             ***DIRECTIONS FOR USING THE MULTICURVE OPTION***          COLF0020
C     1. THE INPUT DECK MUST BE MODIFIED IN THE FOLLOWING MANNER.       COLF0030
C        A.-CARD 1- PJNCHED 022 IN COLS.1 THRU 3.                       COLF0040
C        B.-CARD 2- RIGHT JUSTIFIED IN COL 1 AND 2 THE NUMBER OF        COLF0050
C     GRAPHS TO BE PLOTTED. IN COLS. 3 AND 4 RIGHT JUSTIFIED A ZERO OR  COLF0060
C     ONE. A ONE IF CALCOMP OUTPUT IS DESIRED OR A 0 IF PLOTP IS DES-   COLF0070
C     IRED. UP TO 10 GRAPHS MAY BE DRAWN                                COLF0080
C        C.-CARD 3- THE NUMBER OF THE X AXIS OF THE FRST CURVE IN COLS  COLF0090
C     1 AND 2,THE NUMBER OF THE Y AXIS IN COL 3 AND 4 ETC, FOR EACH     COLF0100
C     CURVE. THE NUMBERS ARE FOUND IN THE SUBROUTINE BELOW.             COLF0110
C        D.-CARD 4- IN COL 1 THRU 48 THE FIRST LINE OF THE GRAPH TITLE. COLF0120
C     THIS SHOULD CONTAIN YOUR NAME FOR IDENTIFIACTION.                 COLF0130
C             *** ONLY 3 RUNS MAY BE MADE***                            COLF0140
C     2.THE FOLLOWING CARDS MUST APPEAR IN EACH RUN.                    COLF0150
C        A.-CARD 1.-PUNCHED 021 IN COL. 1-3.                            COLF0160
C        B.-CARD 2.-CONTAINS THE NUMBERS OF THE VARIABLES IN I2 FORMAT  COLF0170
C     UP TO 8 VARIABLES THAT WILL APPEAR IN SUMMARY ONE. IF NO PRINT    COLF0180
C     IS DESIRED EITHER SET IVERT=0 OR INSERT A BLANK CARD.             COLF0190
C        C.-CARD 3.-AS ABOVE FOR SUMMARY TWO.                           COLF0200
C        D.-CARD 4.- PUNCHED 020 IN COL. 1 -3.                          COLF0210
C        E.-CARD 5.-A 1 FOR EACH GRAPH IF THIS IS THE FIRST OF MORE     COLF0220
C     THAN ONE GRAPH.A 2 FOR EACH GRAPH IF THIS IS THE SECOND CURVE,    COLF0230
C     OR A 3 IF THIS IS THE LAST CURVE. IF ONY ONE CURVE IS TO BE       COLF0240
C     DRAWN, THEN A 0 FOR EACH GRAPH.                                   COLF0250
      COMMON/AXIS/NXYS(32)                                              COLF0260
      COMMON/COLUMN/IVERT,ILATRL                                        COLF0270
      COMMON /CURVE/NCURV(10)                                           COLF0280
      COMMON/EQNCO/ NEQS,TOL(20),JQQ                                    COLF0290
      COMMON/GRAF/NGRAF,NDRW                                            COLF0300
      COMMON /HEADG/TICRD(6)                                            COLF0310
      COMMON/STEP/ STEP2                                                COLF0320
      COMMON /SUM/ ISUM1(8),ISUM2(8)                                    COLF0330
      REAL*8 TICRD                                                      COLF0340
      REAL LABEL                                                        COLF0350
      REAL LAB(4)/'    ','   1','   2','   3'/                          COLF0360
      REAL*8 NAMES(74)/'TIME    ','        ','WAVE HEI','GHT     ','DRAFCOLF03 0
     1T   ','        ','PITCH AN','GLE     ','PLENUM P','RESSURE ','BOW COLF0380
     2HEAV','E ACC   ','CG HEAVE','ACC     ','FAN POWE','R       ','ROLLCOLF0390
     3 ANG','LE      ','YAW ANGL','E       ','SWAY ACC','        ','SURGCOLF0400
     4E SP','EED     ','TURN RAD','IUS     ','YAW RATE','        ','X DICOLF0410
     5SPLA','CEMENT  ','Y DISPLA','CEMENT  ','AIR FLOW',' IN     ','AIR COLF0420
     6FLOW',' OUT    ','NET FORC','E X DIR ','BUBBLE  ','DRAG    ','SIDECOLF0430
     7SLIP',' ANGLE  ','RUDDER  ','ANGLE   ','SURGE AC','CEL     ','STERCOLF0440
     8N AC','CEL     ','TOTAL TH','RUST    ','ROLL RAT','E P     ','ROLLCOLF0450
     9 ACC','EL      ','PITCH AC','CEL     ','YAW ACCE','L       ','BOW COLF0460
     *SEAL','PRESSURE','STN SEAL','PRESSURE','PITCH RA','TE Q    ',     COLF04 0
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```
*'PTN STEA','DY STATE','POSITION','-ACTUAL ','  MAIN F','AN   RPM '/
 REAL*8 TITLE(12)                                                   COLF0480
 REAL*8 LINE2(2)/'PLOT IS ',' VERSUS '/                             COLF0490
 REAL*8 NAMEX(2),NAMEY(2),INAME(16)                                 COLF0500
 EQUIVALENCE (TITLE(1),TICRD(1)),(TITLE(2),TICRD(2)),(TITLE(3),TI   COLF0510
1CRD(3)),(TITLE(4),TICRD(4)),(TITLE(5),TICRD(5)),(TITLE(6),TICRD(   COLF0520
26))                                                                COLF0530
 DIMENSION PVQQ(35),XOUT(900),YOUT(900),AFILE(8)
 EQUIVALENCE (PVQQ(1),TIME),(PVQQ(2),ETA),(PVQQ(3),Z),(PVQQ(4),THETCOLF0550
1A),(PVQQ(5),PB),(PVQQ(6),BOWACC),(PVQQ(7),ACC),(PVQQ(8),FANPWR),(PCOLF0560
2VQQ(9),PHI),(PVQQ(10),PSI),(PVQQ(11),ACCLAT),(PVQQ(12),U),(PVQQ(   COLF0570
313),TRADUS),(PVQQ(14),R),(PVQQ(15),X),(PVQQ(16),Y),(PVQQ(17),QIN),COLF0580
4(PVQQ(18),QOUT),(PVQQ(19),GFXXX),(PVQQ(20),FXPWAV),(PVQQ(21),      COLF0590
5BETAS),(PVQQ(22),DLRDR),(PVQQ(23),SRGACC),(PVQQ(24),STNACC),       COLF0600
6(PVQQ(25),THRUST),(PVQQ(26),PDEG),(PVQQ(27),PDOT),(PVQQ(28),QDOT),COLF0610
7(PVQQ(29),RDOT),(PVQQ(30),PBARB),(PVQQ(31),PBARS),(PVQQ(32),QDEG) COLF0620
8,(PVQQ(33),POSIT1),(PVQQ(34),POSIT2),(PVQQ(35),EMRPM)
 IF(JQQ.NE.2) GO TO 1                                               COLF0630
 WRITE(6,777) STEP2                                                 COLF0640
777 FORMAT('0',4X,'THIS RUN USED VARIABLE STEP SIZE',/,'0',4X,'THE MINCOLF0650
 1IMUM STEPSIZE RECORDED DURING THE RUN WAS',2X,E30.5)              COLF0660
1 ENDFILE 1                                                         COLF0670
 REWIND 1                                                           COLF0680
 TITLE(7)=LINE2(1)                                                  COLF0690
 TITLE(10)=LINE2(2)                                                 COLF0700
 IF(NGRAF.EQ.0) GO TO 11                                            COLF0710
 J=1                                                                COLF0720
 NGF=NGRAF                                                          COLF0730
 INDEX=NGRAF*2                                                      COLF0740
 DO 19 I=1,INDEX,2                                                  COLF0750
 INDX=NXYS(I)                                                       COLF0760
 INDY=NXYS(I+1)                                                     COLF0770
 IQ=0                                                               COLF0780
7 READ(1,END=8)TIME,ETA,Z,THETA,PB,BOWACC,ACC,FANPWR,PHI,PSI,ACCLA  COLF0790
 1T,U,TRADUS,R,X,Y,QIN,QOUT,GFXXX,FXPWAV,BETAS,DLRDR,SRGACC,         COLF0800
 2STNACC,THRUST,PDEG,PDOT,QDOT,RDOT,PBARB,PBARS,QDEG                 COLF0810
 3,POSIT1,POSIT2,EMRPM
 IF(IQ.GE.900) GO TO 8                                              COLF0820
 IQ=IQ+1                                                            COLF0830
 XOUT(IQ)=PVQQ(INDX)                                                COLF0840
 YOUT(IQ)=PVQQ(INDY)                                                COLF0850
 GO TO 7                                                            COLF0860
8 REWIND 1                                                          COLF0870
 INX=INDX*2                                                         COLF0880
 INY=INDY*2                                                         COLF0890
 NAMEX(1)=NAMES(INX-1)                                              COLF0900
 NAMEX(2)=NAMES(INX)                                                COLF0910
 NAMEY(1)=NAMES(INY-1)                                              COLF0920
```

```
      NAMEY(2)=NAMES(INY)                                                COLF0930
      IF(NDRW.EQ.1) GO TO 20                                             COLF0940
      CALL PLOTP(XOUT,YOUT,-IQ,0)                                        COLF0950
      WRITE(6,301) NAMEX,NAMEY                                           COLF0960
  301 FORMAT(' ',20X,2A8,' IS THE INDEPENDENT VARIABLE AND ',2A8,' THE DCOLF0970
     1EPENDENT VARIABLE')                                                COLF0980
      GO TO 19                                                           COLF0990
   20 TITLE(8)=NAMEY(1)                                                  COLF1000
      TITLE(9)=NAMEY(2)                                                  COLF1010
      TITLE(11)=NAMEX(1)                                                 COLF1020
      TITLE(12)=NAMEX(2)                                                 COLF1030
      NCUR=NCURV(J)                                                      COLF1040
      IF(NCUR.NE.0) GO TO 25                                             COLF1050
      LABEL=LAB(1)                                                       COLF1060
      CALL DRAW(IQ,XOUT,YOUT,NCUR,0,L1BEL,TITLE,0,0,0,0,0,0,6,8,1,LAST)  COLF1070
      J=J+1                                                              COLF1080
      GO TO 19                                                           COLF1090
   25 WRITE(2)IQ,NCUR,NGF,LABEL,(TITLE(K),K=1,12),(XOUT(L),YOUT(L),L=1,ICOLF1100
     1Q)                                                                 COLF1110
      NGF=NGF-1                                                          COLF1120
   19 CONTINUE                                                           COLF1130
      IF((NGF.EQ.0).AND.(NCUR.EQ.3)) GO TO 26                            COLF1140
   11 IF(IVERT.NE.1) GO TO 14                                            COLF1150
      WRITE(6,100)                                                       COLF1160
  100 FORMAT('0',50X,'***SUMMARY ONE***',/,'0')                          COLF1170
      K=0                                                                COLF1180
      DO 31 I=1,8                                                        COLF1190
      IF(ISUM1(I).NE.0) K=K+1                                            COLF1200
   31 CONTINUE                                                           COLF1210
      NUM1=K                                                             COLF1220
      IF(K.EQ.0) GO TO 14                                                COLF1230
      N=K*2                                                              COLF1240
      J=1                                                                COLF1250
      DO 33 I=1,NUM1                                                     COLF1260
      IDEX=ISUM1(I)*2                                                    COLF1270
      INAME(J)=NAMES(IDEX-1)                                             COLF1280
      INAME(J+1)=NAMES(IDEX)                                             COLF1290
      J=J+2                                                              COLF1300
   33 CONTINUE                                                           COLF1310
       WRITE(6,300)(INAME(I),I=1,N)                                      COLF1320
  300 FORMAT('0',16A8)                                                   COLF1330
      GO TO 4                                                            COLF1340
   26 ENDFILE 2                                                          COLF1350
      REWIND 2                                                           COLF1360
      NGF=NGRAF                                                          COLF1370
      J=1                                                                COLF1380
   27 READ(2,END=38)IQ,NCUR,NGRAF,LABEL,(TITLE(K),K=1,12),(XOUT(L),YOUT(COLF1390
     1L),L=1,IQ)                                                         COLF1400
```

```
      IF((NGF.EQ.NGRAF).AND.(NCUR.EQ.J)) GO TO 29                       COLF1410
      GO TO 27                                                          COLF1420
   29 LABEL=LAB(J+1)                                                    COLF1430
      CALL DRAW(IQ,XOUT,YOUT,NCUR,0,LABEL,TITLE,0,0,0,0,0,0,6,8,1,LAST) COLF1440
      REWIND 2                                                          COLF1450
      J=J+1                                                             COLF1460
      IF(J.EQ.4) GO TO 38                                               COLF1470
      GO TO 27                                                          COLF1480
   38 NGF=NGF-1                                                         COLF1490
      IF(NGF.EQ.0) GO TO 11                                             COLF1500
      J=1                                                               COLF1510
      GO TO 27                                                          COLF1520
    4 READ(1,END=13)(PVQQ(I),I=1,35)
      DO 35 I=1,NUM1                                                    COLF1540
      J=ISUM1(I)                                                        COLF1550
   35 AFILE(I)=PVQQ(J)                                                  COLF1560
      WRITE(6,400)(AFILE(I),I=1,NUM1)                                   COLF1570
  400 FORMAT('0',8(3X,F10.2,3X))                                        COLF1580
      GO TO 4                                                           COLF1590
   13 REWIND 1                                                          COLF1600
   14 IF(ILATRL.NE.1) GO TO 17                                          COLF1610
      WRITE(6,200)                                                      COLF1620
  200 FORMAT('0',50X,'***SUMMARY TWO***',/,'0')                         COLF1630
      K=0                                                               COLF1640
      DO 32 I=1,8                                                       COLF1650
      IF(ISUM2(I).NE.0) K=K+1                                           COLF1660
   32 CONTINUE                                                          COLF1670
      NUM2=K                                                            COLF1680
      IF(K.EQ.0) GO TO 16                                               COLF1690
      N=K*2                                                             COLF1700
      J=1                                                               COLF1710
      DO 34 I=1,NUM2                                                    COLF1720
      IDEX=ISUM2(I)*2                                                   COLF1730
      INAME(J)=NAMES(IDEX-1)                                            COLF1740
      INAME(J+1)=NAMES(IDEX)                                            COLF1750
      J=J+2                                                             COLF1760
   34 CONTINUE                                                          COLF1770
       WRITE(6,300)(INAME(I),I=1,N)                                     COLF1780
   23 READ(1,END=16)(PVQQ(I),I=1,35)                                    COLF1790
      DO 36 I=1,NUM2                                                    COLF1800
      J=ISUM2(I)                                                        COLF1810
   36 AFILE(I)=PVQQ(J)                                                  COLF1820
      WRITE(6,400)(AFILE(I),I=1,NUM2)                                   COLF1830
      GO TO 23                                                          COLF1840
   16 REWIND 1                                                          COLF1850
   17 RETURN                                                            COLF1860
      END                                                               COLF1870
```

```
C
      SUBROUTINE DMINV (A,N,D)
      DIMENSION A(6,6), PIVOT(6)
      DIMENSION IPVOT(6), INDEX(6,2)
      EQUIVALENCE (IROW,JROW), (ICOL,JCOL)
      D = 1.0
C
      DO 1 J=1,N
      IPVOT(J) = 0
    1 CONTINUE
C
C
      DO 14 I=1,N
      T = 0.0
C
      DO 6 J=1,N
      IF (IPVOT(J)-1) 2,6,2
C
    2 DO 5 K=1,N
      IF (IPVOT(K)-1) 3,5,18
    3 IF (ABS(T)-ABS(A(J,K))) 4,5,5
    4 IROW = J
      ICOL = K
      T = A(J,K)
    5 CONTINUE
C
    6 CONTINUE
C
      IPVOT(ICOL) = IPVOT(ICOL)+1
      IF (IROW-ICOL) 7,9,7
    7 D = -D
C
      DO 8 L=1,N
      T = A(IROW,L)
      A(IROW,L) = A(ICOL,L)
      A(ICOL,L) = T
    8 CONTINUE
C
    9 INDEX(I,1) = IROW
      INDEX(I,2) = ICOL
      PIVOT(I) = A(ICOL,ICOL)
      D = D*PIVOT(I)
      A(ICOL,ICOL) = 1.0
C
      DO 10 L=1,N
      A(ICOL,L) = A(ICOL,L)/PIVOT(I)
   10 CONTINUE
C
```

```
C
      DO 13 LI=1,N
      IF (LI-ICOL) 11,13,11
   11 T = A(LI,ICOL)
      A(LI,ICOL) = 0.0
C
      DO 12 L=1,N
      A(LI,L) = A(LI,L)-A(ICOL,L)*T
   12 CONTINUE
C
   13 CONTINUE
C
   14 CONTINUE
C
C
      DO 17 I=1,N
      L = N-I+1
      IF (INDEX(L,1)-INDEX(L,2)) 15,17,15
   15 JROW = INDEX(L,1)
      JCOL = INDEX(L,2)
C
      DO 16 K=1,N
      T = A(K,JROW)
      A(K,JROW) = A(K,JCOL)
      A(K,JCOL) = T
   16 CONTINUE
C
   17 CONTINUE
C
   18 RETURN
      END
```

```
C
      SUBROUTINE FAN
      INTEGER ON
      COMMON /AIR/ PINF,RHOINF,GAM
      COMMON /FANMAP/ QIN,QBFAN(25),QMFAN(25),QSFAN(25),ENBFAN,ENMFAN,EN
     1SFAN,BRPM,EMRPM,SRPM,NPTSB,NPTSM,NPTSS,PBFAN(25),PMFAN(25),PSFAN(2
     25)
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,I
     1RUD,IPROP,IAERОD,IRHS
      COMMON /SOFTBS/ DSBS,CFBS,PBS,DPBS,YAVGB(10),DELYBS(10),ELMAXB
      COMMON /SOFTSS/ XLF,PSS,SINTH,COSTH,XSS,ZSS,DELYSS,DPSS,ELMAXS,YAV
     1GS(10)
      COMMON /VARBLE/ VAL(40)
      DIMENSION QB(1), QM(1), QS(1), PBOW(1), PM(1), PS(1)
      EQUIVALENCE (VAL(1),TIME), (VAL(2),U), (VAL(3),V), (VAL(4),W), (VA
     1L(5),P), (VAL(6),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VA
     2L(10),Z), (VAL(11),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI)
     3, (VAL(24),PB)
      EQUIVALENCE (VAL(18),FANPWR)
      EQUIVALENCE (QBFAN(1),QB(1)), (QMFAN(1),QM(1)), (QSFAN(1),QS(1)),
     1(PBFAN(1),PBOW(1)), (PMFAN(1),PM(1)), (PSFAN(1),PS(1))
      BRAT = 1700./BRPM
      EMRAT = 1700./EMRPM
      SRAT = 1870./SRPM
      PB1 = PBS-PINF
      PB2 = PB-PINF
      PB3 = PSS-PINF
      PBARB = PB1*BRAT**2
      PBARM = PB2*EMRAT**2
      PBARS = PB3*SRAT**2
      QBOW = ENBFAN*FG1(PBARB,NPTSB,PBOW,QB,IB)/BRAT
      QMAIN = ENMFAN*FG1(PBARM,NPTSM,PM,QM,IM)/EMRAT
      QSTN = ENSFAN*FG1(PBARS,NPTSS,PS,QS,IS)/SRAT
      QIN = QBOW+QMAIN+QSTN
      FANPWR = (QBOW*PB1+QMAIN*PB2+QSTN*PB3)/550.
      IF (IRHS.NE.ON) RETURN
      WRITE (6,1) QBOW,QMAIN,QSTN,PBARB,PBARM,PBARS
      RETURN
C
    1 FORMAT (//4H FAN/32H Q - BOW,MAIN,STERN (CU FT /SEC)3F12.1/28H DEL
     1P - BOW,MAIN,STERN (PSF)3F11.2)
      END
```

```
C
      FUNCTION FG1 (X,N,XT,YT,IX)
      DIMENSION XT(1), YT(1)
      IF (IX.LT.1) IX = 1
      IF (IX.GT.N-1) IX = N-1
      I = SIGN(1.0,X-XT(IX))
    1 IF (IX.LT.1.OR.IX.GE.N) GO TO 3
      IF (XT(IX).GT.X.OR.X.GT.XT(IX+1)) GO TO 2
      C = (X-XT(IX))/(XT(IX+1)-XT(IX))
      GO TO 4
    2 IX = IX+I
      GO TO 1
    3 C = IX/N
      IX = IX-I
    4 FG1 = YT(IX)+C*(YT(IX+1)-YT(IX))
      RETURN
      END
```

```
C
      FUNCTION FG2 (X,Y,NX,NY,XT,YT,ZT,IX,IY)
      DIMENSION XT(NX), YT(NY), ZT(NX,NY)
      IF (IX.LT.1) IX = 1
      IF (IX.GT.(NX-1)) IX=NX-1
      I = SIGN(1.0,X-XT(IX))
    1 IF (IX.LT.1.OR.IX.GE.NX) GO TO 3
      IF (XT(IX).GT.X.OR.X.GT.XT(IX+1)) GO TO 2
      CX = (X-XT(IX))/(XT(IX+1)-XT(IX))
      GO TO 4
    2 IX = IX+I
      GO TO 1
    3 CX = IX/NX
      IX = IX-I
    4 IF (IY.LT.1) IY = 1
      IF (IY.GT.(NY-1)) IY=NY-1
      I = SIGN(1.0,Y-YT(IY))
    5 IF (IY.LT.1.OR.IY.GE.NY) GO TO 7
      IF (YT(IY).GT.Y.OR.Y.GT.YT(IY+1)) GO TO 6
      CY = (Y-YT(IY))/(YT(IY+1)-YT(IY))
      GO TO 8
    6 IY = IY+I
      GO TO 5
    7 CY = IY/NY
      IY = IY-I
    8 CC = CX*CY
      FG2 = ZT(IX,IY)*(1.0-CX-CY+CC)+ZT(IX+1,IY)*(CX-CC)+ZT(IX,IY+1)*(CY
     1-CC)+ZT(IX+1,IY+1)*CC
      RETURN
      END
```

```
C
      SUBROUTINE FORIT (FNT,N,M,A,B,IER)
      DIMENSION A(1), B(1), FNT(1)
C     CHECK FOR PARAMETER ERRORS
      IER = 0
      IF (M) 1,2,2
    1 IER = 2
      RETURN
    2 IF (M-N) 4,4,3
    3 IER = 1
      RETURN
C     COMPUTE AND PRESET CONSTANTS
    4 CONTINUE
      AN = N
      COEF = 2.0/(2.0*AN+1.0)
      PI = 4.*ATAN(1.)
      CONST = PI*COEF
      S1 = SIN(CONST)
      C1 = COS(CONST)
      C = 1.0
      S = 0.0
      J = 1
      FNTZ = FNT(1)
    5 U2 = 0.0
      U1 = 0.0
      I = 2*N+1
C     FORM FOURIER COEFFICIENTS RECURSIVELY
    6 U0 = FNT(I)+2.0*C*U1-U2
      U2 = U1
      U1 = U0
      I = I-1
      IF (I-1) 7,7,6
    7 A(J) = COEF*(FNTZ+C*U1-U2)
      B(J) = COEF*S*U1
      IF (J-(M+1)) 8,9,9
    8 Q = C1*C-S1*S
      S = C1*S+S1*C
      C = Q
      J = J+1
      GO TO 5
    9 A(1) = A(1)*0.5
      RETURN
      END
```

```
C
C
      SUBROUTINE INCON (TIME)
      INTEGER ON
      COMMON /AIR/ PINF,RHOINF,GAM
      COMMON/AXIS/NXYS(32)
      COMMON /BMCO / IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IY
      COMMON /COLUMN/ IVERT,ILATRL
      COMMON /CONST/ PI,RAD,UO
      COMMON /CNTRL/CONTW,CONTQ,CONTTH,QMULT,LOUVER,ACONTZ,ACONTW,ZEQUIL
     1 ,THEQL,ACBASE
      COMMON /CURVE/NCURV(10)
      COMMON / ENGINE / TOUT,THRUST,THRSTO,STHRST,XP,YP,ZP
      COMMON /EQNCO/ NEQS,TOL(20),JQQ
      COMMON /FAIR/ RHOA,XLAERO
      COMMON /FANMAP/QIN,QBFAN(25),QMFAN(25),QSFAN(25),ENBFAN,ENMFAN,
     1 ENSFAN,BRPM,EMRPM,SRPM,NPTSB,NPTSM,NPTSS
     2 ,PBFAN(25),PMFAN(25),PSFAN(25)
      COMMON / FROUDE / FN,FNCRIT
      COMMON/GBOW/ XBOW
      COMMON /GEOM/    WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM
     1,DELS(4,10),XCP,ZCP
      COMMON /GEOMSW/ XAVG(10),DS
      COMMON/GRAF/NGRAF,NDRW
      COMMON /HEADG/TICRD(6)
      COMMON /PWAVE/ FNCON,PWVCON
      COMMON/LEAKER/ ALEAK,CFSS
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,
     -                AMI(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO
      COMMON /MATRIX/ A(6,6)
      COMMON /OPTION/ I3DOF,ISRGE,ITRIM
      COMMON /PLENUM/XLBW,XBBW,ABW,BUBHGT
      COMMON/PLVCQQ/NVI,NVD,NLI,NLD
      COMMON /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT
      COMMON /PRTINT/ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,
     -IRUD,IPROP,IAEROD,IRHS
      COMMON /ROLL/ PHIMAX,TROLL
      COMMON /RUDDR/ DELRUD,RUDON,RUDOFF,RUDRAT,COSRUD,XR,YR,ZR,TANRUD
     1   ,RUDREV,IRDS,TL,RSPAN,RAREA,RASPR,RCLB,RTC
     2   ,RUDMAX,RRDRAT,RRDMAX
      COMMON /RISER/ AMPTC
      COMMON /SLOPE/ WATSLP
      COMMON /SPRAY/NSPDS,UTAB(5),NDRFTS,DEPTAB(8),DRGTAB(40)
      COMMON /SOFTBS/DSBS,CFBS,PBS,DPBS,YAVGB(10),DELYBS(10),ELMAXB
      COMMON /SOFTSS/ XLF,PSS,SINTH,COSTH,XSS,ZSS,DELYSS,DPSS
     1 ,ELMAXS,YAVGS(10)
      COMMON /SIDE/FXSW,FYSW,FZSW,FKSW,FMSW,FNSW,ALSW,YSW,XLSW,CFSW,CDSW
     1,VAREA   ,VCHORD,VSPAN,VANGLE,VCOS,VX,VY,VZ  ,AVBMSW,DELX,VTC
```

```
      COMMON /STABLE/ S(4),ISTAB
      COMMON /STSLR/ CPHI,CPHID
      COMMON /SUM/ ISUM1(8),ISUM2(8)
      COMMON / VALOLD / YOLD(20)
      COMMON /VARBLE/ VAL(40)
      COMMON /VCONTL/ OPTSBH,ORIPOS,BLANK1
      COMMON/VLUVER/ CFVL,VWIDTH,VHEIGH,VTAU,VKONST
      COMMON /WAVE/ ETA(4,11),AW(10),OMEGA(10),DVOLW,NWAVE,BETA,
     1              FXWAV,FYWAV,FZWAV,FKWAV,FMWAV,FNWAV
     2             ,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBBAR
      COMMON /WAVEF/WAVLEN(10),OMEGAE(10),WAVSLP(10),ENCPER(10)
      COMMON /WAVTAB/ NAL,DAL,SAL,NDS,DDS,SDS,NTH,DTH,STH,NBB,DBB,SBB,
     1          AC1(20,5,7),AC2(20,5,7),AC3(20,5,7),AC4(20,5,7),
     2          AC5(20,5,7),AC6(20,5,7),AC7(20,5,7)
     3          ,AC0(20,5,7),AC00(20,5,7),AC8(20,5,7),
     4          AS1(20,5,7),AS2(20,5,7),AS3(20,5,7),AS4(20,5,7),
     5          AS5(20,5,7),AS6(20,5,7),AS7(20,5,7)
     6          ,AS0(20,5,7),AS00(20,5,7),AS8(20,5,7)
     7          ,BB(36),XREF,RX

      DIMENSION ZZZ(14050)
      EQUIVALENCE (ZZZ,NAL)
      EQUIVALENCE              (VAL(2),U),(VAL(3),V),(VAL(4),W),
     1(VAL(5),P),(VAL(6),Q),(VAL(7),R),(VAL(8),PHI),(VAL(9),THETA),
     2(VAL(10),Z),(VAL(11),BMASS),(VAL(21),X),(VAL(22),Y),(VAL(23),PSI),
     3(VAL(24),PB)
      EQUIVALENCE (VAL(12),POSIT1), (VAL(13),POSIT2)
      REAL*8 TICRD
      DIMENSION HEVCON(20)
      DIMENSION TEMP(7),XMO(10)
      DIMENSION TITLC(20)
      DATA HEVCON/20*0.0/
      DATA BEAM,BETAD,DELO,       DLRDO,DSO,ISYS,RMAXO,RONO,RRATO,RREVO,
     1       THSSI,TPRINO,UO,VXO,VZO,XBSI,XCPO,XLTOT,XPO,XRO,XSSI,YPO,
     2 ZPO,ZRO,ZSSI/ 5*0.0,0,19*0.0/

      DO 9 I=1,8
      ISUM1(I)=0
    9 ISUM2(I)=0
      TOUT=1.E6
      PINF=2116.
      RHOINF=.002378
      GAM=1.4
      GO TO 10
 2200 READ(5,3000) NGRAF,NDRW
 3000 FORMAT(2I2)
      READ(5,3001) NXYS
 3001 FORMAT(32I2)
```

```
      READ(5,3002) TICRD
 3002 FORMAT(6A8)
10    READ(5,99) ISYSL,IOPT,(TEMP(I),I=1,7)
      IF( ISYSL .EQ. ISYS .AND. ISYSL.EQ. 13) GOTO 70
      ISYS=ISYSL
      IF((ISYS.LE.0).OR.(ISYS.GT.22)) GO TO 70
      GOTO(100,200,300,400,500,600,700,800,900,1000,1100,1200,1300,
     11400,1500,1600,1700,1800,1900,2000,2100,2200),ISYS

C     PROGRAM CONTROL PARAMETERS
100   CONTINUE
      GOTO (101,102,103,104,105),IOPT
 101  CONTINUE
      STIME=TEMP(1)
      FTIME=TEMP(2)
      DELO=TEMP(3)
      DELPNT=TEMP(4)
      TPRINO=TEMP(5)
      IF (TPRINO.LT.STIME+DELPNT)  TPRINO = STIME+DELPNT
      IF (DELO.GT.DELPNT) DELO=DELPNT
      IF (DELO.EQ.0.0) GO TO 140
      GOTO 10
 2000 READ(5,3003) NCURV
 3003 FORMAT(10I1)
      GO TO 10
 2100 READ(5,2210) ISUM1
      READ(5,2210)ISUM2
 2210 FORMAT(8I2)
      GO TO 10
102   READ (5,191) IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IRUD,
     1 IPROP,IAEROD,IRHS
      GOTO 10
103   READ (5,175) NEQS,JQQ,(TOL(J),J=1,NEQS)
      GOTO 10
 104  READ(5,191) IVERT,ILATRL,NVD,NVI,NLD,NLI
      GO TO 10
 105  CONTINUE
      I3DOF=TEMP(1)
      ISRGE=TEMP(2)
      ITRIM=TEMP(3)
      GO TO 10
  140 WRITE(6,195)
      STOP

C     MASS DISTRIBUTION
  200 G=32.17
      RHO=1.99
      HRHO=RHO/2.
```

```
      GO TO (210,220,230), IOPT
  210 IMM = 0
      WEIGHT = TEMP(1)
      AM = WEIGHT/G
      XS = TEMP(2)
      ZS = TEMP(3)
      AIXX = TEMP(4)
      AIYY = TEMP(5)
      AIZZ = TEMP(6)
      AIXZ = TEMP(7)
C     INERTIA MATRIX OPERATIONS
  212 DO 211 I=1,6
      DO 211 N=1,6
  211 A(I,N) = 0.0
      DO 213 N=1,3
  213 A(N,N)=AM
      A(4,4)=AIXX
      A(5,5)=AIYY
      A(6,6)=AIZZ
      A(4,6)=-AIXZ
      A(6,4)=-AIXZ
      AIMAX=AMAX1(AM,AIXX,AIYY,AIZZ,ABS(AIXZ))
      DO 214 I=1,6
      DO 214 J=1,6
  214 A(I,J)=A(I,J)/AIMAX
      CALL DMINV (A,6,D)
      DO 215 I=1,6
      DO 215 J=1,6
  215 A(I,J)=A(I,J)/AIMAX
      IF (D.NE.0.0) GO TO 10
      WRITE (6,216)
      STOP
C     READ WEIGHT DISTRIBUTION - ASSUME TRANSVERSE (PORT/STBD) SYMMETRY
C        X INPUT DIST. FWD. OF (SIDEWALL) TRANSOM
C        Y INPUT DIST. TO STARBOARD
  220 I = 1
C        Z INPUT DIST. UP FROM KEEL-LINE
  222 READ (5,192) AMI(I),XI(I),YI(I),ZI(I)
      IF (AMI(I).LT.0.0)  GO TO 224
      I = I+1
      IF ( I.GT.201 )  GO TO 70
      GO TO 222
  224 NMASS = I-1
      SUM = 0.0
      SUX = 0.0
      SUZ = 0.0
      DO 225 I=1,NMASS
      AMI(I) = AMI(I)/G
```

```
      SUM = SUM+AMI(I)
      SUX = SUX+AMI(I)*XI(I)
  225 SUZ = SUZ+AMI(I)*ZI(I)
      AM = SUM*2.0
      WEIGHT = AM*G
      XS  = SUX/SUM
      ZS  = SUZ/SUM
      SUM = 0.0
      SUX = 0.0
      SUY = 0.0
      SUZ = 0.0
      DO 226 I=1,NMASS
      XI(I) = XI(I)-XS
      ZI(I) = -ZI(I)+ZS
      AMK = AMI(I)*2.0
      SUX = SUX+AMK*XI(I)*XI(I)
      SUY = SUY+AMK*YI(I)*YI(I)
      SUZ = SUZ+AMK*ZI(I)*ZI(I)
  226 SUM = SUM+AMK*XI(I)*ZI(I)
      AIXX =  SUY+SUZ
      AIYY =  SUX+SUZ
      AIZZ =  SUX+SUY
      AIXZ =  SUM
      GO TO 212
  230 GO TO 10

C     XX AND YY TABLES
300   CONTINUE
      NSTA(1) =  TEMP(1)
      NSTA(2) =  TEMP(2)
      NSTA(3) =  TEMP(3)
      NSTA(4) =  TEMP(4)
      XLTOT=TEMP(5)
      GOTO 10

C     SIDEWALL (INCLUDING APPENDAGES)
400   CONTINUE
      GOTO (401,402,403),IOPT
      GOTO (401,402),IOPT
401   YSW=TEMP(1)
      XLSW=TEMP(2)
      CFSW=TEMP(3)
      CDSW=TEMP(4)
      AVBMSW=TEMP(5)
      READ (10) ZZZ
      REWIND 10
      GOTO 10
402   VANGLE=TEMP(1)/RAD
```

```
      VCOS=COS(VANGLE)                                                  INC 2400
      VSPAN=TEMP(2)                                                     INC 2410
      VCHORD=TEMP(3)                                                    INC 2420
      VXO=TEMP(4)                                                       INC 2430
      VY=TEMP(5)                                                        INC 2440
      VZO=TEMP(6)                                                       INC 2450
      VTC=TEMP(7)                                                       INC 2460
      VAREA=VCHORD*VSPAN                                                INC 2470
      GOTO 10                                                           INC 2480
C     READ SPRAY DRAG TABLES                                            INC 2490
  403 CONTINUE                                                          INC 2500
      NSPDS =TEMP(1)                                                    INC 2510
      NDRFTS=TEMP(2)                                                    INC 2520
      READ(5,1950) (UTAB(I),I=1,NSPDS)                                  INC 2530
      READ(5,1950) (DEPTAB(I),I=1,NDRFTS)                               INC 2540
      DO 404 I=1,NSPDS                                                  INC 2550
      UTAB(I)=UTAB(I)*1.6878                                            INC 2560
      JU=I+(NDRFTS-1)*NSPDS                                             INC 2570
      READ(5,1950) (DRGTAB(J),J=I,JU,NSPDS)                             INC 2580
  404 CONTINUE                                                          INC 2590
      GO TO 10                                                          INC 2600
                                                                        INC 2610
C     STERNSEAL                                                         INC 2620
  500 CONTINUE                                                          INC 2630
      XSSI=TEMP(1)                                                      INC 2640
      ZSSI=TEMP(2)                                                      INC 2650
      ALEAK=TEMP(3)                                                     INC 2660
      CFSS=TEMP(4)                                                      INC 2670
      THSSI=TEMP(5)                                                     INC 2680
      DPSS=TEMP(6)                                                      INC 2690
      XLF=TEMP(7)                                                       INC 2700
      SINTH=SIN(THSSI/RAD)                                              INC 2710
      COSTH=COS(THSSI/RAD)                                              INC 2720
      ELMAXS=XLF*COSTH                                                  INC 2730
      GO TO 10                                                          INC 2740
                                                                        INC 2750
C     BOWSEAL                                                           INC 2760
  600 CONTINUE                                                          INC 2770
      XBSI=TEMP(1)                                                      INC 2780
      CFBS=TEMP(2)                                                      INC 2790
      DPBS=TEMP(3)                                                      INC 2800
      ELMAXB=TEMP(4)                                                    INC 2810
      GOTO 10                                                           INC 2820
                                                                        INC 2830
C     PLENUM                                                            INC 2840
  700 CONTINUE                                                          INC 2850
      GO TO (705,710),IOPT                                              INC 2860
  705 CONTINUE                                                          INC 2870
```

```
      XLBW=TEMP(1)
      XBBW=TEMP(2)
      WIDTH=TEMP(4)
      XL=TEMP(5)
      XCPO=TEMP(6)
      BUBHGT=TEMP(7)
      ABW=XBBW*XLBW
      AB=WIDTH*XL
      VCLNOM=(ABW+AB)*BUBHGT/2.
      GOTO 10
  710 CONTINUE
      FNCRIT=TEMP(1)
      GO TO 10

C     PROPULSION
800   CONTINUE
      GO TO (805,810),IOPT
  805 CONTINUE
      XPO=TEMP(1)
      YPO=TEMP(2)
      ZPO=TEMP(3)
      THRSTO=TEMP(4)
      STHRST=TEMP(5)
      GO TO 10
  810 TOUT=TEMP(1)
      IF(TOUT.LT.STIME) TOUT=STIME
      GOTO 10

C     RUDDER
900   CONTINUE
      GO TO (905,910,915),IOPT
  905 XRO = TEMP(1)
      YR=TEMP(2)
      ZRO = TEMP(3)
      RSPAN=TEMP(4)
      RASPR=TEMP(5)
      RAREA=TEMP(6)
      RCLB=2.*PI*RASPR/(RASPR+3.)
      RTC=TEMP(7)
      GO TO 10
  910 DLRDO=TEMP(1)
      RONO=TEMP(2)
      RMAXO=TEMP(3)
      RRATO=TEMP(4)
      RREVO=TEMP(5)
      RRDMAX=TEMP(6)
      RRDRAT=TEMP(7)
      GO TO 10
```

```
915   CONTINUE
      GOTO 10

C     AERODYNAMICS
1000  CONTINUE
      XLAERO=TEMP(1)
      BEAM=TEMP(2)
      RHOA=.5*RHOINF*XLAERO*BEAM
      GOTO 10

C     WAVES
1100  CONTINUE
      IWAVSW=IOPT
      NWAVE=TEMP(1)
      IF(NWAVE .EQ. 0) GOTO 10
      IF(NWAVE .GT. 10) GOTO 70
      BETAD=TEMP(2)
      BETA=BETAD/RAD
      COSBET=COS(BETA)
      SINBET=SIN(BETA)
      TC = 1.0
      GOTO ( 1104,1106) ,IWAVSW
1104  DO 1105 I=1,NWAVE
1105  READ(5,1190) OMEGA(I),AW(I)
      GOTO 10
1106  DO 1107 I=1,NWAVE
1107  READ (5,1190) WAVLEN( I) ,AW(I)
      GOTO 10

C     INITIAL CONDITIONS
1200  CONTINUE
      UO=TEMP(1)
      UO=UO
      THETO = TEMP(2)
      DSO = TEMP(3)
      DELPI=TEMP(4)
      DPHI=TEMP(5)
      GO TO 10

1300  CONTINUE
C     INPUT COMPLETED. 1) PRINT ALL INPUT
      WRITE(6,2004) TITLC
      WRITE (6,2001) STIME,FTIME,DELO,TPRINO,DELPNT
      WRITE (6,2002) IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IRUD,
     1 IPROP,IAEROD,IRHS
      WRITE(6,2021) I3DOF,ISRGE,ITRIM
      WRITE (6,2003) NEQS, (TOL(J),J=1,NEQS)
      WRITE (6,219) WEIGHT,XS,ZS,AIXX,AIYY,AIZZ,AIXZ
```

```
      WRITE(6,217)A,AIMAX
      WRITE (6,2018) NSTA
      WRITE (6,490) YSW,XLSW,CFSW,CDSW,VANGLE,VSPAN,VCHORD,VXO,VY,VZO,
     1 AVBMSW,VTC
      WRITE (6,491) NAL,DAL,SAL,NDS,DDS,SDS,NTH,DTH,STH,NBB,DBB,SBB
      IF (IMM.GT.0)  WRITE(6,1549)    (XMO(J),J=1,IMNX)
      WRITE (6,1519) IMM,IMNX,IMNY,IBMFIL,BTIME,IMT
      IF (IMM.GT.0)  WRITE(6,1559) (YMI(J),J=1,IMNY)
      WRITE (6,2010) XLBW,XBBW
      WRITE (6,2011) XL,WIDTH,XCPO,VOLNOM,BUBHGT
      WRITE (6,2020) DELPI
      WRITE(6,2009) FNCRIT,XLTOT
      WRITE (6,2028) ENBFAN,BRPM,ENMFAN,EMRPM,ENSFAN,SRPM
      WRITE(6,2029) CFVL, VWIDTH,VHEIGH,VTAU,VKONST,POSIT1,OPTSBH
      WRITE (6,2022) HEVCON
      WRITE (6,2013) XRO,YR,ZRO,RONO,RMAXO,RRATO,RREVO,DLRDO
     1  ,RSPAN,RASPR,RAREA,RCLB,RTC
      THRUST =THRSTO*2.
      WRITE (6,2012)        XPO,YPO,ZPO,TOUT,THRUST,STHRST
      WRITE (6,2027) XLAERO,BEAM
      WRITE (6,2026) XBSI,CFBS,DPBS,ELMAXB
      WRITE (6,2025) XSSI,ZSSI,ALEAK,CFSS,THSSI,DPSS,XLF
      WRITE (6,2017) UO,THETO,DSO

C                 AND 2) INITIALIZE VARIABLES FOR CALCS.
      DO 1302 I=1,40
 1302 VAL(I) = 0.0
      U = UO*1.6889
      XSS=-(XS-XSSI)
      ZSS=ZS-ZSSI
      THETA = THETO/RAD
      PHI=DPHI/RAD
      THEQL=THETA
      DS = DSO/12.
      Z=-ZS+DS
      ZEQUIL=Z
      PHIMAX=0.
      TROLL=0.
      DELRUD=DLRDO/RAD
      TANRUD=TAN(DELRUD)
      COSRUD =COS(DELRUD)
      RUDON=RONO
      RUDMAX=RMAXO
      RUDRAT=RRATO
      RUDREV=RREVO
      IF ( RUDRAT.NE.0.0 )  RUDOFF = RUDON+RUDMAX/RUDRAT
      IF (RUDREV .LT. RUDOFF) RUDREV=RUDOFF
      IRDS=0
```

```
      TL=0.0
C     WAVE PARAMETERS TABLE
      IF(NWAVE .EQ.0) GOTO 1321
      AMPTC=1.30287
      GOTO(1310,1315),IWAVSW
1310  DO 1311 I=1,NWAVE
1311  WAVLEN(I)=2.*PI*G/(OMEGA(I)*OMEGA(I))
      GOTO 1317
1315  DO 1316 I=1,NWAVE
1316  OMEGA(I)=SQRT(2.*PI*G/WAVLEN(I))
1317  CONTINUE

C     CALCULATE INITIAL FREQUENCIES OF ENCOUNTER
      DO 1318 I=1,NWAVE
      WAVSLP(I) = 360.0*AW(I)/WAVLEN(I)
      OMEGAE(I) =2.*PI*(SQRT(G*WAVLEN(I)/(2.*PI))-U*COSBET)/WAVLEN(I)
      ENCPER(I) = 2.0*PI/OMEGAE(I)
1318  CONTINUE
      WRITE (6,1191) NWAVE,BETAD,(OMEGA(I),OMEGAE(I),WAVLEN(I),AW(I),
     1                WAVSLP(I),ENCPER(I),I=1,NWAVE)
      GOTO 1322
 1321 WRITE (6,1192)
1322  CONTINUE
      DO 1303 I=1,4
      DO 1303 N=1,11
 1303 ETA(I,N) = 0.0
      DVOLW = 0.0
      FXWAV = 0.0
      FYWAV = 0.0
      FZWAV = 0.0
      FKWAV = 0.0
      FMWAV = 0.0
      FNWAV = 0.0
      ZBAR=Z
      PHIBAR=PHI
      THEBAR=THETA
      TIME=STIME
      DELT = DELO
      TPRINT=TPRINO-DELPNT
      PWVCON=4.*WEIGHT/(RHO*G*XLBW)
      FNCON=SQRT(XLBW*G)
C     CALCULATE SLOPE OF WATER SURFACE INSIDE PLENUM
      WATSLP=(PWVCON*DELPI*.37/(U/FNCON)**1.5655981)/WEIGHT
      VX=VXO-XS
      VZ = ZS-VZO
      XP=XPO-XS
      XR = XRO-XS
      YP=YPO
```

```
      ZP=ZS-ZPO
      ZR = ZS-ZRO
      IF (IMM.EQ. 0) GO TO 1305
      DO 1304 J=1,IMNX
 1304 XMI(J) = XMO(J) - XS
 1305 CONTINUE
      XCP = XCPO-XS
      ZCP = ZS-BUBHGT
      XBS=XBSI-XS
      N=NSTA(3)
      ANG=-PI/2.
      DANG=PI/(N-1)
      RBS=XBBW/2.
      DSBS=RBS*DANG
      DO 1364 J=1,N
      XX(3,J)=XBS+RBS*COS(ANG)
      YY(3,J)=RBS*SIN(ANG)
      ANG=ANG+DANG
 1364 CONTINUE
      N=N-1
      DO 1367 J=1,N
      YAVGB(J)=(YY(3,J+1)+YY(3,J))/2.
      DELYBS(J)=YY(3,J+1)-YY(3,J)
 1367 CONTINUE
      N=NSTA(4)
      DELYSS=XBBW/(N-1)
      DO 1365 J=1,N
      XX(4,J)=-XS
      YY(4,J)=-.5*XBBW+(J-1)*DELYSS
 1365 CONTINUE
      N=N-1
      DO 1368 J=1,N
      YAVGS(J)=(YY(4,J+1)+YY(4,J))/2.
 1368 CONTINUE
      XBOW=XLTOT-XS
      N=NSTA(1)
      DELX=XBSI/(N-1)
      DO 1309 J=1,2
      DO 1309 I=1,N
      XX(J,I)=(I-1)*DELX-XS
 1309 YY(J,I)= YSW*(2*J-3)
      WRITE(6,1366) ((XX(J,N),N=1,11),(YY(J,N),N=1,11),J=1,4)
 1366 FORMAT (//17H XX AND YY ARRAYS /14H PORT SIDEWALL /2(11F10.2/),
     1 15H STBD. SIDEWALL /2(11F10.2/),9H BOW SEAL /2(11F10.2/),
     2 11H STERN SEAL /2(11F10.2/))
      N=NSTA(1)-1
      DO 1308 I=1,N
 1308 XAVG(I)=DELX*(2*I-1)/2.-XS
```

```
      CALL WAVES(TIME)
C     INITIALIZE BUBBLE PRESSURE, ABSOLUTE (PSF)
      PB=PINF+DELPI
      PBBAR=DELPI
      PSS=PB+DPSS
      PBS=PB+DPBS
      AB=XL*(XBBW-(XBBW-WIDTH)*(ZS+Z)/BUBHGT)
      VOL=VOLNOM-.5*(AB+ABW)*(Z+ZS)-DVOLW
     1 +.5*WATSLP*XL*AB
      BMASS=(PB/PINF)**(1./GAM)*VOL*RHOINF
      WRITE (6,2023)
      RETURN
C     RUN TERMINATOR
 1400 WRITE(6,98)
      STOP
C     BENDING MOMENT
 1500 GO TO (1510,1520,1530,1540), IOPT
 1510 IMM = TEMP(1)
      IF (IMM.GT.3)  GO TO 70
      IMNX = TEMP(2)
      IF (IMNX.GT.10)  GO TO 70
      IMNY = TEMP(3)
      IF (IMNY.GT.7)  GO TO 70
      IBMFIL = TEMP(4)
      BTIME = TEMP(5)
      IF (IMM.EQ.3)  IMT = TEMP(6)
      GO TO 10
 1520 DO 1521 J=1,7
 1521 XMO(J) = TEMP(J)
      IF (IMNX.LE.7)  GO TO 10
      READ 1522, (XMO(J),J=8,IMNX)
      GO TO 10
 1530 DO 1531 J=1,IMNY
 1531 YMI(J) = TEMP(J)
      GO TO 10
 1540 CONTINUE
      GO TO 10
C     NOT USED
 1600 CONTINUE
      GO TO 10
C     NOT USED
 1700 CONTINUE
      GOTO 10
```

```
C     TITLE CARD (ALL 80 COLUMNS )
 1800 READ  (5,2022)  TITLC
      GO TO 10

C     FAN MAPS
1900  CONTINUE
      GO TO (1905,1910,1915,1920),IOPT
1905  CONTINUE
      ENBFAN=TEMP(1)
      BRPM=TEMP(2)
      NPTSB=TEMP(3)
      READIN=TEMP(4)
      IF (READIN .EQ. 0.0) GO TO 10
      READ (5,1950) (PBFAN(J),J=1,NPTSB)
      READ (5,1950) (QBFAN(J),J=1,NPTSB)
      GO TO 10
1910  CONTINUE
      ENMFAN=TEMP(1)
      EMRPM=TEMP(2)
      NPTSM=TEMP(3)
      READIN=TEMP(4)
      IF (READIN .EQ. 0.0) GO TO 10
      READ (5,1950) (PMFAN(J),J=1,NPTSM)
      READ (5,1950) (QMFAN(J),J=1,NPTSM)
      GO TO 10
1915  CONTINUE
      ENSFAN=TEMP(1)
      SRPM=TEMP(2)
      NPTSS=TEMP(3)
      READIN=TEMP(4)
      IF (READIN .EQ. 0.0) GO TO 10
      READ (5,1950) (PSFAN(J),J=1,NPTSS)
      READ (5,1950) (QSFAN(J),J=1,NPTSS)
      GO TO 10
C     HEAVE ACCELERATION CONTROLLER DATA
 1920 CONTINUE
      CFVL=TEMP(1)
      VWIDTH=TEMP(2)
      VHEIGH=TEMP(3)
      VTAU=TEMP(4)
      VKONST=TEMP(5)
      ORIPOS=TEMP(6)
      OPTSBH=TEMP(7)
      READ(5,2022) HEVCON
      GO TO 10
1950  FORMAT(8F10.0)
C     ERROR IN INPUT
```

```
   70 CONTINUE                                                          INC 6240
      WRITE (6,79) ISYS                                                 INC 6250
      STOP                                                              INC 6260
   79 FORMAT(34H INPUT ERROR - - - STOP - -  ISYS= ,I3)                 INC 6270
   98 FORMAT(1H1,20(/),50X,19H COMPLETED ALL RUNS )                     INC 6280
 99   FORMAT(I3,I2,7F10.0)                                              INC 6290
  191 FORMAT (16I5)                                                     INC 6300
  192 FORMAT (5F10.0)                                                   INC 6310
  195 FORMAT(///10X,65HERROR IN INPUT --- DELT AND/OR DELPNT EQUALS ZEROINC 6320
     1 --- JOB ABORTED )                                                INC 6330
 175  FORMAT (2I2/(8F10.0))                                             INC 6340
  216 FORMAT(///10X,82HERROR IN INPUT --- INPUT INERTIA ELEMENTS LEAD TOINC 6350
     1 ZERO DETERMINANT --- JOB ABORTED )                               INC 6360
  217 FORMAT(22H INERTIA MATRIX, AIMAX  6E15.4/(22X,6E15.4))            INC 6370
  219 FORMAT(30H WEIGHT, C.G., INERTIA MOMENTS 7F12.3)                  INC 6380
  305 FORMAT ( 11F7.0 )                                                 INC 6390
  490 FORMAT(15H SIDEWALL INPUT 12(F8.3,1X))                            INC 6400
  491 FORMAT(26H SIDEWALL TABLE PARAMETERS 4(I4,F7.3,F7.3))             INC 6410
1190  FORMAT(2F10.0)                                                    INC 6420
 1191 FORMAT(/12HONO OF WAVES I2,10H BETA(DEG)F5.0/15H OMEGA(RAD/SEC) , INC 6430
     15X,16H OMEGAE(RAD/SEC) 5X,16H WAVE LENGTH(FT) 5X,14H AMPLITUDE(FT)INC 6440
     - 5X,16HMAX  SLOPE (DEG)5X,13HPERIOD,E(SEC)/(F8.4,12X,F8.4,4F20.3))INC 6450
 1192 FORMAT(/11HOCALM WATER)                                           INC 6460
 1519 FORMAT(32HOMOMENT CALC. CONTROL PARAMETERS 4I5, F8.3, I5 )        INC 6470
 1522 FORMAT ( 5X,7F10.0)                                               INC 6480
 1549 FORMAT(22H MOMENT CALCS. AT X OF 11F10.3)                         INC 6490
 1559 FORMAT(22H MOMENT CALCS. AT Y OF 11F10.3)                         INC 6500
 2004 FORMAT(33H1SES MOTIONS AND LOADS PROGRAM - 20A4,/)                INC 6510
 2001 FORMAT(23H START AND FINISH TIMES 2F10.2/                         INC 6520
     -22H INITIAL TIME INTERVAL F12.4/                                  INC 6530
     -18H START PRINTING AT F8.2,17H IN INCREMENTS OF F8.2)             INC 6540
 2002 FORMAT(24H INTERMEDIATE PRINT TAGS 16I5)                          INC 6550
 2003 FORMAT(39H NO. OF STATE EQUATIONS, AND TOLERANCESI5/(10X,10E12.2))INC 6560
 2010 FORMAT(34HOPLENUM, LENGTH AND WIDTH AT WATER 2F12.4)              INC 6570
 2011 FORMAT(34H PLENUM, LENGTH AND WIDTH AT HULL  2F12.4/              INC 6580
     -          35H PLENUM, CENTER OF PRESSURE AT HULL F12.4/           INC 6590
     -23H PLENUM, NOMINAL VOLUME F12.1,10X, 6HHEIGHT F12.4)             INC 6600
 2009 FORMAT(23HOCRITICAL FROUDE NUMBER F15.4,5X,19H TOTAL CRAFT LENGTH INC 6610
     1          F15.4)                                                  INC 6620
 2012 FORMAT(/33H PROPULSION, X, Y, Z COORDINATES  3F12.4/              INC 6630
     -           33H PROPULSION, TOUT, THRUST, STHRST  3F12.2/)         INC 6640
 2013 FORMAT(/28HORUDDER, X, Y, Z COORDINATES  3F12.4/                  INC 6650
     -           41H RUDDER, ON, MAX, RATE, REVERSE, INITIAL  5F12.4/   INC 6660
     -           33H RUDDER,SPAN,ASPECT,AREA,CLB,T/C  5F12.4)           INC 6670
 2017 FORMAT(/39HOINITIAL CONDITIONS, VELOCITY (KNOTS) = F7.2, 5X,      INC 6680
     -           13HPITCH (DEG) = F8.3,5X,12HDRAFT (IN) = F8.2)         INC 6690
 2018 FORMAT( 49H NUMBER OF STATIONS, SIDEWALLS (P+S), SEALS (B+S) ,4I5)INC 6700
 2020 FORMAT( 38H PLENUM, INITIAL PRESSURE, GAGE (PSF)  F8.2)           INC 6710
```

```
2021 FORMAT(70H PROGRAM OPTION SWITCH SETTINGS (LATERAL PLANE,CONSTANT
    -SPEED,TRIM)        3I5)
2022 FORMAT (20A4 )
2023 FORMAT ( 1H1 )
2025 FORMAT( 16H STERNSEAL INPUT  7F12.4 )
2026 FORMAT( 16H BOWSEAL INPUT    7F12.4 )
2027 FORMAT( 19H0AERODYNAMICS INPUT  7F12.4)
2028 FORMAT( 33H0FANS, NO. + RPM, BOW,MAIN,STERN  3(F10.0,F10.1))
2029 FORMAT (/37H HEAVE ACCELERATION CONTROLLER INPUT ,7F8.3)
     END
```

```
C
      SUBROUTINE INTGRL (TIME)
      INTEGER ON
      COMMON /BMCO/ IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IY
      CCMMON /EQNCO/ NEQS,TOL(20),JQQ
      CCMMON /KSWTCH/ ITHRST
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AM
     1I(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO
      COMMON /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,I
     1RUD,IPROP,IAEROD,IRHS
      COMMON /STABLE/ S(4),ISTAB
      COMMON /STEP/ STEP2
      COMMON /VALOLD/ YOLD(20)
      COMMON /VARBLE/ VAL(40)
      EQUIVALENCE (VAL(1),X), (VAL(2),Y(1))
      DIMENSION Y(20), ERROR(20)
      REAL K1(20),K2(20),K3(20),K4(20),K5(20)
      DATA IPASS/0/
      STEP2 = 1.0
      IF ((TIME+DELT).LE.TPRINT) GO TO 1
      DEL = DELT
      DELT = TPRINT-TIME
      IPASS = 1
    1 X = TIME
C
C
      DO 2 J=1,NEQS
      Y(J) = YOLD(J)
    2 CONTINUE
C
C
      ITHRST = 1
      CALL RHS (K1)
      ITHRST = 2
      IMT = 0
      IF (IACCEL.NE.ON) GO TO 3
      ACCLAT = (K1(2)+Y(1)*Y(6))/G
      WRITE (6,20) ACCLAT,DELT
    3 ON = 2
    4 H = DELT/3.
      X = TIME+H
C
C
      DO 5 J=1,NEQS
    5 Y(J) = YOLD(J)+H*K1(J)
C
C
```

```
      CALL RHS (K2)                                                     INTG 480
C                                                                       INTG 490
C                                                                       INTG 500
      DO 6 J=1,NEQS                                                     INTG 510
    6 Y(J) = YOLD(J)+.5*H*(K1(J)+K2(J))                                 INTG 520
C                                                                       INTG 530
C                                                                       INTG 540
      CALL RHS (K3)                                                     INTG 550
      X = TIME+.5*DELT                                                  INTG 560
C                                                                       INTG 570
C                                                                       INTG 580
      DO 7 J=1,NEQS                                                     INTG 590
    7 Y(J) = YOLD(J)+.375*H*(K1(J)+3.*K3(J))                            INTG 600
C                                                                       INTG 610
C                                                                       INTG 620
      CALL RHS (K4)                                                     INTG 630
      X = TIME+DELT                                                     INTG 640
C                                                                       INTG 650
C                                                                       INTG 660
      DO 8 J=1,NEQS                                                     INTG 670
    8 Y(J) = YOLD(J)+.5*H*(3.*K1(J)-9.*K3(J)+12.*K4(J))                 INTG 680
C                                                                       INTG 690
C                                                                       INTG 700
      CALL RHS (K5)                                                     INTG 710
      IF (JQQ.EQ.1) GO TO 9                                             INTG 720
C                                                                       INTG 730
C                                                                       INTG 740
      DO 9 J=1,NEQS                                                     INTG 750
      ERROR(J) = (K1(J)-4.5*K3(J)+4.*K4(J)-.5*K5(J))*H/5.0              INTG 760
      IF (ABS(ERROR(J)).GT.TOL(J)) GO TO 15                             INTG 770
    9 CONTINUE                                                          INTG 780
C                                                                       INTG 790
C                                                                       INTG 800
C                                                                       INTG 810
C                                                                       INTG 820
      DO 10 J=1,NEQS                                                    INTG 830
      Y(J) = YOLD(J)+.5*H*(K1(J)+4.*K4(J)+K5(J))                        INTG 840
   10 YOLD(J) = Y(J)                                                    INTG 850
C                                                                       INTG 860
C                                                                       INTG 870
      TIME = TIME+DELT                                                  INTG 880
      IF (IPASS.EQ.1) GO TO 14                                          INTG 890
      IF (JQQ.EQ.1) GO TO 12                                            INTG 900
C                                                                       INTG 910
C                                                                       INTG 920
      DO 11 J=1,NEQS                                                    INTG 930
      IF (ABS(ERROR(J)).GT.TOL(J)/16.) GO TO 13                         INTG 940
   11 CONTINUE                                                          INTG 950
```

```
C
C
      DELT = 2.*DELT
      IF (DELT.GT.DELPNT) DELT=DELPNT
   12 RETURN
   13 STEP2 = DELT
      GO TO 12
   14 DELT = DEL
      STEP2 = DELT
      IPASS = 0
      GO TO 12
   15 DELT = DELT/2.
      IF (DELT.LT.1.E-6) GO TO 18
      IF (JQQ.EQ.2) GO TO 17
      WRITE (6,22) TIME,DELT,J,ERROR(J),TOL(J)
   16 IPASS = 0
      GO TO 4
   17 STEP1 = DELT
      IF (STEP1.LT.STEP2) STEP2=STEP1
      GO TO 16
   18 WRITE (6,21)
      WRITE (6,19) TIME,DELT,(K1(J),J=1,NEQS),VAL
      STOP
C
C
   19 FORMAT (/10X,23HINTGRL TIME,DELT,K1,VAL/2E15.4/2(5E15.4/),5(8E15.4
     1/))
   20 FORMAT (1H0,9X,33HTOTAL LATERAL ACCELERATION (G) = F12.4,12X,5HDT
     1= E15.4)
   21 FORMAT (1H1,10X,44HDELTA TIME LESS THAN 1.0E-6  -  -  JOB STOPS)
   22 FORMAT (/10X,5HINT-J2E30.5,I5,2E20.5)
      END
```

```
C
      SUBROUTINE PROP
      INTEGER ON
      COMMON /CONST/ PI,RAD,UO
      COMMON /FPROP/ FX,FY,FZ,FK,FM,FN
      COMMON /ENGINE/ TOUT,THRUST,THRSTO,STHRST,XP,YP,ZP
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,I
     1RUD,IPROP,IAEROD,IRHS
      COMMON /VARBLE/ VAL(40)
      EQUIVALENCE (VAL(1),TIME), (VAL(2),U), (VAL(3),V), (VAL(4),W), (VA
     1L(5),P), (VAL(6),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VA
     2L(10),Z), (VAL(11),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI)
     3, (VAL(24),PB)
C     CHECK ENGINE OUT CONDITION (PORT)
      NPROP = 2
      IF (TIME.GE.TOUT) NPROP=1
      FX = 0.0
      FY = 0.0
      FZ = 0.0
      FK = 0.0
      FM = 0.0
      FN = 0.0
C
      DO 1 I=1,NPROP
      PJ = 2*I-3
      FX = FX+THRSTO
      FY = FY+STHRST*PJ
      FZ = FZ-THRSTO*THETA
      FK = FK+(THRSTO*THETA*YP-STHRST*ZP)*PJ
      FM = FM+THRSTO*ZP
      FN = FN+(STHRST*XP+THRSTO*YP)*PJ
    1 CONTINUE
C
      IF (IPROP.NE.ON) RETURN
      WRITE (6,2) FX,FY,FZ,FK,FM,FN
      RETURN
    2 FORMAT(/10X,22HPROP FX,FY,FZ,FK,FM,FN  /6E15.4)
      END
```

```
C
      SUBROUTINE RHS (VALUE)
      INTEGER ON
      COMMON /AIR/ PINF,RHOINF,GAM
      COMMON /BMCO/ IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IY
      COMMON /COLUMN/ IVERT,ILATRL
      COMMON /CONST/ PI,RAD,UO
      COMMON /CNTRL/ CONTW,CONTQ,CONTTH,QMULT,LOUVER,ACONTZ,ACONTW,ZEQUI
     1L,THEQL,ACBASE
      COMMON /ENGINE/ TOUT,THRUST,THRSTO,STHRST,XP,YP,ZP
      COMMON /EQNCO/ NEQS,TOL(20),JQQ
      COMMON /FANMAP/ QIN,QBFAN(25),QMFAN(25),QSFAN(25),ENBFAN,ENMFAN,EN
     1SFAN,BRPM,EMRPM,SRPM,NPTSB,NPTSM,NPTSS,PBFAN(25),PMFAN(25),PSFAN(2
     25)
      COMMON /FAERO/ FXAED,FYAED,FZAED,FKAED,FMAED,FNAED
      COMMON /FORBS/ FXBS,FYBS,FZBS,FKBS,FMBS,FNBS,QLBS
      COMMON /FORSS/ FXSS,FYSS,FZSS,FKSS,FMSS,FNSS,QLSS,FMS
      COMMON /FPROP/ FXP,FYP,FZP,FKP,FMP,FNP
      COMMON /FROUDE/ FN,FNCRIT
      COMMON /FRUD/ FXRUD,FYRUD,FZRUD,FKRUD,FMRUD,FNRUD
      COMMON /GBOW/ XBOW
      COMMON /GEOM/ WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM,DELS(4,
     110),XCP,ZCP
      COMMON /GEOMBS/ DETABX(11),DETABT(11),ARM1B(10),ARM2B(10),DFBS(10)
     1,TSKIB(10)
      COMMON /GEOMSS/ DETADX(11),DETADT(11),ARM1S(10),DFSS(10),TSKIS(10)
     1,ARM2S(10)
      COMMON /KSWTCH/ ITHRST
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AM
     1I(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO
      COMMON /MATRIX/ A(6,6)
      COMMON /MSIDW/ DF(2,10),DSWAV(2,10),FXH(2),FYH(2),FZH(2),FMH(2),FN
     1H(2),VFY(2),VFZ(2),FXV
      COMMON /MWAVE/ FXW(2),FYW(2),FZW(2),FKW(2),FMW(2),FNW(2)
      COMMON /OPTION/ I3DOF,ISRGE,ITRIM
      COMMON /PLENUM/ XLBW,XBBW,ABW,BUBHGT
      COMMON /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,I
     1RUD,IPROP,IAEROD,IRHS
      COMMON /PWAVE/ FNCON,PWVCON
      COMMON /RUDDR/ DELRUD,RUDON,RUDOFF,RUDRAT,COSRUD,XR,YR,ZR,TANRUD,R
     1UDREV,IRDS,TL,RSPAN,RAREA,RASPR,RCLB,RTC,RUDMAX,RRDRAT,RRDMAX
      COMMON /SLOPE/ WATSLP
      COMMON /SIDE/ FXSW,FYSW,FZSW,FKSW,FMSW,FNSW,ALSW,YSW,XLSW,CFSW,CDS
     1W,VAREA,VCHORD,VSPAN,VANGLE,VCOS,VX,VY,VZ,AVBMSW,DELX,VTC
      COMMON /SOFTBS/ DSBS,CFBS,PBS,DPBS,YAVGB(10),DELYBS(10),ELMAXB
      COMMON /SOFTSS/ XLF,PSS,SINTH,COSTH,XSS,ZSS,DELYSS,DPSS,ELMAXS,YAV
     1GS(10)
```

```
      COMMON /VALOLD/ YOLD(20)                                          RHS
      COMMON /VARBLE/ VAL(40)                                           RHS
      COMMON /VCONTL/ OPTSBH,ORIPOS,BLANK1                              RHS
      COMMON /VLUVER/ CFVL,VWIDTH,VHEIGH,VTAU,VKONST                    RHS
      COMMCN /WAVE/ ETA(4,11),AW(10),OMEGA(10),DVOLW,NWAVE,BETA,FXWAV,FYRHS
     1WAV,FZWAV,FKWAV,FMWAV,FNWAV,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBRHS
     2BAR                                                               RHS
      EQUIVALENCE (VAL(1),TIME), (VAL(2),U), (VAL(3),V), (VAL(4),W), (VARHS
     1L(5),P), (VAL(6),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VARHS
     2L(10),Z), (VAL(11),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI)RHS
     3, (VAL(24),PB)                                                    RHS
      EQUIVALENCE (VAL(18),FANPWR)                                      RHS
      EQUIVALENCE (VAL(35),PBARB), (VAL(36),PBARS)                      RHS
      EQUIVALENCE (VAL(12),POSIT1), (VAL(13),POSIT2)                    RHS
      DIMENSION PACCEL(2)                                               RHS
      DIMENSION ACCEL(3), ANGACL(3)                                     RHS
      DIMENSION GF(6), VALUE(20)                                        RHS
      DATA PLDIF1/0.0/,PLDIF2/0.0/                                      RHS
      DATA NOTIN/0/,KCRL/0/,KT/0/                                       RHS
      DATA GF1/0.0/,GFFAN/0.0/,RPMCRL/0.0/                              RHS
      DATA UDIF1/0.0/,UDIF2/0.0/                                        RHS
      DATA PACCEL/2*0.0/,ACCEL/3*0.0/,ANGACL/3*0.0/                     RHS
C                                                                       RHS
C                                                                       RHS
      DO 1 JJ=1,2                                                       RHS
    1 PACCEL(JJ) = 0.0                                                  RHS
C                                                                       RHS
C                                                                       RHS
C                                                                       RHS
C                                                                       RHS
      DO 2 J=1,20                                                       RHS
    2 VALUE(J) = 0.0                                                    RHS
C                                                                       RHS
C                                                                       RHS
      KTRY = 0                                                          RHS
    3 CONTINUE                                                          RHS
      AB = XL*(XBBW-(XBBW-WIDTH)*(ZS+Z)/BUBHGT)                         RHS
      VOL = VOLNOM-.5*(AB+ABW)*(Z+ZS)-DVOLW+.5*WATSLP*XL*AB             RHS
      PB = PINF*(BMASS/(VOL*RHOINF))**GAM                               RHS
      PBAR = PB-PINF                                                    RHS
      PBS = 1.250*PBAR+PINF                                             RHS
      PSS = 1.25*PBAR+PINF                                              RHS
      ABPB = PBAR*AB                                                    RHS
C     CALCULATION OF BUBBLE WAVE MAKING DRAG                            RHS
      FN = U/FNCON                                                      RHS
      CF = .37/(FN**1.5655981)                                          RHS
      FXPWAV = -PWVCON*PBBAR*CF                                         RHS
      FLOW = SQRT(2.*ABS(PBAR)/RHOINF)*SIGN(1.,PBAR)                    RHS
```

```
      QLSW = CFSW*ALSW*FLOW
      CALL BOWSL
      CALL STNSL
      GF(1) = FXBS+FXSS+FXSW+FXRUD+FXP+FXWAV+FXAED+FXPWAV
      IF (ITHRST.NE.ITRIM) GO TO 4
      THRSTO = THRSTO-GF(1)/2.
      THRUST = THRSTO*2.
      GF(1) = 0.0
    4 CONTINUE
      GF(2) = -R*U*AM+FYBS+FYSS+FYSW+FYRUD+FYP+FYWAV+FYAED
      GF(3) = WEIGHT-ABPB+FZBS+FZSS+FZSW+FZRUD+FZP+FZWAV+FZAED
      GF(4) = FKBS+FKSS+FKSW+FKRUD+FKP+FKWAV+FKAED+ABPB*PHI*(-Z)
      GF(5) = FMBS+FMSS+FMSW+FMRUD+FMP+FMWAV+FMAED+ABPB*(XCP-THETA*Z)+FX
     1PWAV*ZS
      GF(6) = FNBS+FNSS+FNSW+FNRUD+FNP+FNWAV+FNAED
      IF (I3DOF.NE.1) GO TO 5
      GF(3) = 0.0
      GF(5) = 0.0
    5 CONTINUE
C
C
      DO 6 I=1,6
      VALUE(I) = 0.0
C
C
      DO 6 J=1,6
      VALUE(I) = VALUE(I)+A(I,J)*GF(J)
    6 CONTINUE
C
C
      VALUE(7) = P
      VALUE(8) = Q
      VALUE(9) = W
      POSIT1 = ORIPOS
      IF (OPTSBH.EQ.0.0.OR.OPTSBH.EQ.2.0) GO TO 9
      PACCEL(2) = ABS(ACCEL(3))*.70
      IF (PACCEL(2).LT.PACCEL(1)) GO TO 7
      KC = 0
      VALUE(11) = (.91*PACCEL(2)-POSIT1)/(.91*VTAU)
      GO TO 8
    7 KC = KC+1
      IF (KC.EQ.1) VCAP = POSIT1
      VTAU2 = VTAU*10.
      VALUE(11) = (VCAP*VTAU2-POSIT1)/VTAU2
    8 CONTINUE
      PACCEL(1) = PACCEL(2)
      VALUE(12) = (VKONST*(POSIT1-.25*ACCEL(3)-POSIT2))
      POVTSS = POSIT1*VHEIGH
```

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      IF (POSIT2.LT.0.0) POSIT2=0.0                                     RHS 1440
      POVTSP = POSIT2*VHEIGH                                            RHS 1450
      VTARSS = POVTSS*VWIDTH                                            RHS 1460
      VTARSP = POVTSP*VWIDTH                                            RHS 1470
      QVNTSP = VTARSP*FLOW*CFVL                                         RHS 1480
      QVNTSS = VTARSS*FLOW*CFVL                                         RHS 1490
      GO TO 10                                                          RHS 1500
    9 CONTINUE                                                          RHS 1510
      QVNTSS = 0.0                                                      RHS 1520
      QVNTSP = 0.0                                                      RHS 1530
   10 CONTINUE                                                          RHS 1540
      IF (I3DOF.EQ.1) GO TO 11                                          RHS 1550
C     BUBBLE PRESSURE EQUATION                                          RHS 1560
      QOUT = QLBS+QLSS+QLSW+QVNTSP                                      RHS 1570
      QCNTRL = 0.0                                                      RHS 1580
      CALL FAN                                                          RHS 1590
      VALUE(10) = RHOINF*(QIN-QOUT-QCNTRL)                              RHS 1600
      GO TO 12                                                          RHS 1610
   11 CONTINUE                                                          RHS 1620
      VALUE(10) = 0.0                                                   RHS 1630
   12 CONTINUE                                                          RHS 1640
C     WRITE DATA FILE FOR MOMENT AND SHEAR CALCS., IF REQUIRED          RHS 1650
      IF (IMT.NE.1) GO TO 13                                            RHS 1660
      NBS = NSTA(3)-1                                                   RHS 1670
      NSS = NSTA(4)-1                                                   RHS 1680
      NSSL = NSS/2+1                                                    RHS 1690
      WRITE (IBMFIL) (VAL(I),I=1,24),ZBAR,PHIBAR,THEBAR,FXW,FYW,FZW,FKW,RHS 1700
     1FMW,FNW,(VALUE(I),I=1,10),DF,DSWAV,FXH,FYH,FZH,FMH,FNH,VFY,VFZ,FXVRHS 1710
     2,FXRUD,FYRUD,FXP,FYP,FZP,FZSS,FKSS,FMSS,FXBS,FZBS,FXAED,FYAED,FZAERHS 1720
     3D,FMAED,FNAED,FXPWAV,FXSS,FKBS,FMBS,FNBS,FNSS,(TSKIS(I),DFSS(I),I=RHS 1730
     4NSSL,NSS),(TSKIB(I),DFBS(I),ARM1B(I),ARM2B(I),I=1,NBS)            RHS 1740
   13 CONTINUE                                                          RHS 1750
C     CONSTANT LONGITUDINAL VELOCITY ( U )                              RHS 1760
      IF (ISRGE.EQ.1) VALUE(1)=0.0                                      RHS 1770
      IF (ON.NE.1) RETURN                                               RHS 1780
C                                                                       RHS 1790
C                                                                       RHS 1800
      DO 14 I=1,3                                                       RHS 1810
      ACCEL(I) = VALUE(I)/G                                             RHS 1820
      ANGACL(I) = VALUE(I+3)*RAD                                        RHS 1830
   14 CONTINUE                                                          RHS 1840
C                                                                       RHS 1850
C                                                                       RHS 1860
      BOWACC = ACCEL(3)-XBOW*VALUE(5)/G                                 RHS 1870
      STNACC = ACCEL(3)+XS*VALUE(5)/G                                   RHS 1880
      IF (IVERT.NE.ON) GO TO 15                                         RHS 1890
      ZD = Z+ZS                                                         RHS 1900
      THETAR = THETA*RAD                                                RHS 1910
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15 IF (ILATRL.NE.ON) GO TO 19                                          RHS 1920
   DEPSI = PSI*RAD                                                     RHS 1930
   RDEG = R*RAD                                                        RHS 1940
   BETAS = -V/U*RAD                                                    RHS 1950
   ACCLAT = (VALUE(2)+U*R)/G                                           RHS 1960
   DLRDR = DELRUD*RAD                                                  RHS 1970
   DPHI = PHI*RAD                                                      RHS 1980
   PDEG = P*RAD                                                        RHS 1990
   QDEG = Q*RAD                                                        RHS 2000
   ZDIN = ZD*12.                                                       RHS 2010
   UKNOTS = U/1.6889                                                   RHS 2020
   IF (OPTSBH.EQ.0.0.OR.OPTSBH.EQ.1.0) GO TO 16                        RHS 2030
   IF (KTRY.EQ.1) GO TO 16                                             RHS 2040
   UDIF = UO-UKNOTS                                                    RHS 2050
   GF1 = 50.                                                           RHS 2060
   GF2 = 500.                                                          RHS 2070
   RPMCRL = GF1*VTARSS+GF2*UDIF                                        RHS 2080
   EMRPM = 1700.+RPMCRL                                                RHS 2090
   KTRY = 1                                                            RHS 2100
   GO TO 3                                                             RHS 2110
16 CONTINUE                                                            RHS 2120
   IF (R.EQ.0.0) GO TO 17                                              RHS 2130
   TRADUS = U/R                                                        RHS 2140
   GO TO 18                                                            RHS 2150
17 TRADUS = 1.E8                                                       RHS 2160
18 WRITE (1) TIME,VAL(16),ZDIN,THETAR,PBAR,BOWACC,ACCEL(3),FANPWR,DPHRHS 2170
  1I,DEPSI,ACCLAT,UKNOTS,TRADUS,RDEG,X,Y,QIN,QOUT,GF(1),FXPWAV,BETAS,RHS 2180
  2DLRDR,ACCEL(1),STNACC,THRUST,PDEG,VALUE(4),VALUE(5),VALUE(6),PBARBRHS 2190
  3,PBARS,QDEG,POSIT1,POSIT2,EMRPM                                     RHS 2200
19 IF (IRHS.NE.ON) RETURN                                              RHS 2210
   WRITE (6,20) PBAR,FANPWR,QIN,QLBS,QLSW,QLSS                         RHS 2220
   WRITE (6,21) AB,VOL                                                 RHS 2230
   WRITE (6,22) VALUE,VAL                                              RHS 2240
   WRITE (6,23) GF,ACCEL,ANGACL                                        RHS 2250
   WRITE (6,24) BOWACC,STNACC                                          RHS 2260
   RETURN                                                              RHS 2270
C                                                                      RHS 2280
C                                                                      RHS 2290
20 FORMAT (//10X,3HRHS20HGAGEPRESS.(PSF)=F7.2,5X,21HFAN POWER REQD (HRHS 2300
  1P) =F8.2,5X,27HFAN FLOW RATE (CU FT/SEC) =F9.2,//31H LEAKAGE FLOW RHS 2310
  2RATES (CU FT/SEC)//11H BOW SEAL =F9.2,11H SIDEWALL =F9.2,13H STERNRHS 2320
  3 SEAL =F9.2)                                                        RHS 2330
21 FORMAT (/13H PLENUM AREA=F9.2,10X,14HPLENUM VOLUME=F10.2)           RHS 2340
22 FORMAT (//12H VALUE ARRAY2(/10E13.4)/10H VAL ARRAY4(/10E13.4))      RHS 2350
23 FORMAT (/10X,24HTOTAL FORCES AND MOMENTS6E12.4/10X,24HACCELERATIONRHS 2360
  1S G,DEG/SEC26E12.4)                                                 RHS 2370
24 FORMAT (/10X,16HBOW ACCEL. (G) =E12.4,21H   STERN ACCEL. (G) =E12.RHS 2380
  14)                                                                  RHS 2390
```

RHS 2400

END

```
C
      SUBROUTINE RUDDER                                                 RUD
      INTEGER ON                                                        RUD
      COMMON /CONST/ PI,RAD,UO                                          RUD
      COMMON /FRUD/ FX,FY,FZ,FK,FM,FN                                   RUD
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AMRUD
     1I(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO                         RUD
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IRUD
     1RUD,IPROP,IAEROD,IRHS                                             RUD
      COMMON /RUDDR/ DELRUD,RUDON,RUDOFF,RUDRAT,COSRUD,XR,YR,ZR,TANRUD,RRUD
     1UDREV,IRDS,TL,RSPAN,RAREA,RASPR,RCLB,RTC,RUDMAX,RRDRAT,RRDMAX     RUD
      COMMON /VARBLE/ VAL(40)                                           RUD
      EQUIVALENCE (VAL(1),TIME), (VAL(2),U), (VAL(3),V), (VAL(4),W), (VARUD
     1L(5),P), (VAL(6),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VARUD
     2L(10),Z), (VAL(11),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI)RUD
     3, (VAL(24),PB)                                                    RUD
      EQUIVALENCE (VAL(18),FANPWR)                                      RUD
      DATA ENU/1.28E-5/                                                 RUD
C     CALCULATE PROGRAMMED RUDDER DEFLECTION                            RUD
      IF (RUDREV.EQ.0.) GO TO 1                                         RUD
      IF (IRDS.EQ.1) GO TO 1                                            RUD
      IF (TIME.LT.RUDREV) GO TO 1                                       RUD
      IRDS = 1                                                          RUD
      TL = TIME                                                         RUD
      RUDON = RUDREV                                                    RUD
      RUDRAT = -RRDRAT                                                  RUD
      RUDOFF = RUDREV-(RUDMAX-RRDMAX)/RUDRAT                            RUD
      RUDMAX = RRDMAX                                                   RUD
    1 CONTINUE                                                          RUD
      IF (TIME.LE.RUDON.OR.TIME.GE.RUDOFF) GO TO 2                      RUD
      DELRDL = DELRUD                                                   RUD
      DELRUD = DELRDL+(TIME-TL)*RUDRAT/RAD                              RUD
    2 CONTINUE                                                          RUD
      IF (TIME.GE.RUDOFF) DELRUD=RUDMAX/RAD                             RUD
      TL = TIME                                                         RUD
C     SIDE FORCE ON RUDDER                                              RUD
      DSR = Z+ZS-XR*THETA                                               RUD
      ENDFAC = (1.+DSR/(DSR+RSPAN))                                     RUD
      ENDFAC = 1.                                                       RUD
      VH = V+XR*R-ZR*P                                                  RUD
      QQ = HRHO*U*U*RAREA                                               RUD
      EFFANG = DELRUD-ENDFAC*VH/U                                       RUD
      FY = 2.*QQ*ENDFAC*RCLB*EFFANG                                     RUD
C     DRAG FORCE ON RUDDER                                              RUD
      REY = U*(RAREA/RSPAN)/ENU                                         RUD
      CFR = .427/(ALOG10(REY)-.407)**2.64                               RUD
      PI8 = PI/8.                                                       RUD
      CD = 2.*CFR+PI8*RTC*RTC*(1.+G*RSPAN/(U*U))+RCLB*EFFANG*EFFANG     RUD
```

```
      FX = -2.*CD*RAREA*HRHO*U*U
      FZ = 0.
      FK = -ZR*FY
      FM = FX*ZR
      FN = XR*FY
      IF (IRUD.NE.ON) RETURN
      WRITE (6,3) FX,FY,FZ,FK,FM,FN
      RETURN
C
    3 FORMAT (/10X,24HRUDDER FX,FY,FZ,FK,FM,FN/6E15.4)
      END
```

```
C
      SUBROUTINE SAM
      WRITE (6,1)
      RETURN
C
    1 FORMAT (1H1,'YOU HAVE CALLED A DUMMY SAM SUBROUTINE.'/
     110X,'CHANGE TO BH2SES TO USE THE SAM SUBROUTINE.')
      END
```

```
C
      SUBROUTINE SIDEWL
      INTEGER ON
      COMMON /AIR/ PINF,RHOINF,GAM
      COMMON /BMCO/ IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IY
      COMMON /CONST/ PI,RAD,UO
      COMMON /GEOM/ WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM,DELS(4,
     110),XCP,ZCP
      COMMON /GEOMSW/ XAVG(10),DS
      COMMON /KSWTCH/ ITHRST
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AM
     1I(20I),XI(201),YI(201),ZI(201),XS,ZS,HRHO
      COMMON /MSIDW/ DF(2,10),DSWAV(2,10),FXH(2),FYH(2),FZH(2),FMH(2),FN
     1H(2),VFY(2),VFZ(2),FXV
      COMMON /PLENUM/ XLBW,XBBW,ABW,BUBHGT
      COMMON /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,I
     1RUD,IPROP,IAEROD,IRHS
      COMMON /SIDE/ FX,FY,FZ,FK,FM,FN,ALSW,YSW,XLSW,CFSW,CDSW,VAREA,VCHO
     1RD,VSPAN,VANGLE,VCOS,VX,VY,VZ,AVBMSW,DELX,VTC
      COMMON /SLOPE/ WATSLP
      COMMON /SPRAY/ NSPDS,UTAB(5),NDRFTS,DEPTAB(8),DRGTAB(40)
      COMMON /VARBLE/ VAL(40)
      COMMON /WAVE/ ETA(4,11),AW(10),OMEGA(10),DVOLW,NWAVE,BETA,FXWAV,FY
     1WAV,FZWAV,FKWAV,FMWAV,FNWAV,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PB
     2BAR
      COMMON /WAVTAB/ NAL,DAL,SAL,NDS,DDS,SDS,NTH,DTH,STH,NBB,DBB,SBB,AC
     11(20,5,7),AC2(20,5,7),AC3(20,5,7),AC4(20,5,7),AC5(20,5,7),AC6(20,5
     2,7),AC7(20,5,7),AC0(20,5,7),AC00(20,5,7),AC8(20,5,7),AS1(20,5,7),A
     3S2(20,5,7),AS3(20,5,7),AS4(20,5,7),AS5(20,5,7),AS6(20,5,7),AS7(20,
     45,7),AS0(20,5,7),AS00(20,5,7),AS8(20,5,7),BB(36),XREF,RX
      EQUIVALENCE (VAL(2),U), (VAL(3),V), (VAL(4),W), (VAL(5),P), (VAL(6
     1),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VAL(10),Z), (VAL(
     211),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI), (VAL(24),PB)
      DIMENSION GAP(2,11), DSW(2,11)
      DATA ENU/1.28E-5/
      MID = (NSTA(3)+1.)/2.
C     GAP OR WETTED DRAFT CALCULATION
      GAPT = 0.0
C
      DO 2 J=1,2
      N = NSTA(J)
C
      DO 2 K=1,N
      DD = ZS+Z+YY(J,K)*PHI-XX(1,K)*THETA+ETA(J,K)
      DH = DD-(XX(3,MID)-XX(J,K))*WATSLP
      IF (DH.LT.BUBHGT) GO TO 1
      IF (VAL(1)-TOLD.LT.DELPNT) GO TO 1
```

```
      TOLD = VAL(1)
      WRITE (6,15) XX(J,K),VAL(1),DH
    1 CONTINUE
      GAP(J,K) = (SIGN(1.,DD)-1.)*DD/2.
      GAPT = GAPT+GAP(J,K)
      DSW(J,K) = (SIGN(1.,DD)+1.)*DD/2.
    2 CONTINUE
C
      IF (GAPT.EQ.0.0) GO TO 4
      WRITE (6,16) VAL(1),((GAP(I,J),J=1,11),I=1,1),GAPT,((GAP(I,J),J=1,
     111),I=2,2)
C     LEAKAGE AREA
    4 ALSW = 0.0
C
      DO 5 J=1,2
      N = NSTA(J)-1
C
      DO 5 I=1,N
      ALSW = ALSW+(GAP(J,I)+GAP(J,I+1))*DELX/2.
    5 CONTINUE
C
C     CROSS-FLOW DRAG ON SIDEWALLS
      FYD = 0.0
      FKD = 0.0
      FND = 0.0
C
      DO 6 I=1,2
      N = NSTA(I)-1
C
      DO 6 J=1,N
      DSWAV(I,J) = (DSW(I,J)+DSW(I,J+1))/2.
      VREL = V+XAVG(J)*R-(ZS-DSWAV(I,J)/2.)*P
      DF(I,J) = -HRHO*CDSW*VREL*ABS(VREL)*DELX*DSWAV(I,J)
      FYD = FYD+DF(I,J)
      FND = FND+DF(I,J)*XAVG(J)
    6 FKD = FKD-(ZS-DSWAV(I,J)/2.)*DF(I,J)
C
C     SET UP STERN LIMIT OF FORCE DETERMINATION
      XSS = -XS
      GO TO 7
      ENTRY SIDWLM
      XSS = XMI(IX)
    7 IP = 1.+(THETA*RAD-STH)/DTH
      IP = MAX0(MIN0(IP,NTH),1)
      IP1 = MIN0(IP+1,NTH)
      DTHETA = (IP-1)*DTH+STH
      DIP = (THETA*RAD-DTHETA)/DTH
C     CALC REYNOLDS NO. AND DRAG COEFF.
```

```
      REY = U*XLSW/ENU
      CDT = .427/(ALOG10(REY)-.407)**2.64
C     SIDEWALL FORCES, P/S
C
      DO 12 J=1,2
      WAREA = 0.0
      N = NSTA(J)-1
      NI = (XSS+XS)*N/XLSW+1.5
C
      DO 8 I=NI,N
      ZOR1 = 1.
      IF (DSWAV(J,I).EQ.0.0) ZOR1=0.0
    8 WAREA = WAREA+DELX*(2.*DSWAV(J,I)+ZOR1*AVBMSW)
C
      IF (NI.GT.N) WAREA = 0.0
      FXH(J) = -HRHO*CDT*WAREA*U*U
      PM1 = 2*J-3
      YLSW = PM1*YSW
      DS = Z+ZS+YLSW*PHI
      DSS = DS-XSS*THETA
      ZOR1 = (SIGN(1.,DSS)+1.)/2.
      DSS = DSS*ZOR1
      IDSS = 1.5+(DSS-SBB)/DBB
      IDSS = MIN0(NBB,IDSS)
      BS = BB(IDSS)
      ZOR1 = (SIGN(1.,DSS)+1.)/2.
      DSS = DSS*ZOR1
      DRBOW = DSS-(XX(J,N+1)-XSS)*THETA
      IF (DRBOW.LT.0.0) DRBOW=0.0
      A33S = (RHO*PI*BS**2)/8.
      A22S = (RHO*.8*PI*DSS**2)/2.
      IF (THETA.LT.0.0) A22S=.8*RHO*PI*DRBOW*DRBOW/2.
      DSR = DS-(XREF-XS)*THETA
      ID = 1.+(DSR*12.-SDS)/DDS
      ID = MAX0(MIN0(ID,NDS),1)
      DDSR = (ID-1)*DDS+SDS
      ID1 = MIN0(ID+1,NDS)
      DID = (DSR*12.-DDSR)/DDS
      BCO = ACO(1,ID,IP)
      BCOO = ACOO(1,ID,IP)
      BC2 = AC2(1,ID,IP)
      BC5 = AC5(1,ID,IP)
      BC6 = AC6(1,ID,IP)
      BCO = BCO+DID*(ACO(1,ID1,IP)-BCO)+DIP*(ACO(1,ID,IP1)-BCO+DID*(ACO(
     11,ID1,IP1)-ACO(1,ID,IP1)-ACO(1,ID1,IP)+BCO))
      BCOO = BCOO+DID*(ACOO(1,ID1,IP)-BCOO)+DIP*(ACOO(1,ID,IP1)-BCOO+DID
     1*(ACOO(1,ID1,IP1)-ACOO(1,ID,IP1)-ACOO(1,ID1,IP)+BCOO))
      BC2 = BC2+DID*(AC2(1,ID1,IP)-BC2)+DIP*(AC2(1,ID,IP1)-BC2+DID*(AC2(
```

```
     11,ID1,IP1)-AC2(1,ID,IP1)-AC2(1,ID1,IP)+BC2))
      BC5 = BC5+DID*(AC5(1,ID1,IP)-BC5)+DIP*(AC5(1,ID,IP1)-BC5+DID*(AC5(
     11,ID1,IP1)-AC5(1,ID,IP1)-AC5(1,ID1,IP)+BC5))
      BC6 = BC6+DID*(AC6(1,ID1,IP)-BC6)+DIP*(AC6(1,ID,IP1)-BC6+DID*(AC6(
     11,ID1,IP1)-AC6(1,ID,IP1)-AC6(1,ID1,IP)+BC6))
C     SHIFT MOMENT CENTER FROM XREF TO C.G.
      BC00 = BC00-(XS-XREF)*BC0
      BC6 = BC6-(XS-XREF)*BC5
C     CALCULATE SPRAY DRAG FOR A SINGLE SIDE WALL
      IF (VAL(1).EQ.STIME) SPRYDG=FG2(U,DRBOW,NSPDS,NDRFTS,UTAB,DEPTAB,D
     1RGTAB,ISPD,IDEP)
      FXH(J) = FXH(J)-SPRYDG
C     HYDROSTATIC AND HYDRODYNAMIC FORCES
      FZH(J) = -G*BC0-U*U*A33S*THETA-U*A33S*W+Q*U*(-BC2+A33S*XSS)-U*A33S
     1*P*YLSW
      FMH(J) = -U*XSS*XSS*A33S*Q+G*BC00+U*(A33S*XSS+BC2)*(W+U*THETA+YLSW
     1*P)
      FYH(J) = -A22S*U*(V+XSS*R-ZS*P)
      FNH(J) = FYH(J)*XSS-U*((V-ZS*P)*BC5+R*BC6)
C
C     ADD VERTICAL FORCE DUE TO DEADRISE PROJECTION OF LATERAL FORCE
C
      CTNDR = 0.0
      IF (DSS.LE.0.0) GO TO 9
      CTNDR = (BS-BB(1))/DSS
      IF (THETA.LT.0.0) CTNDR=.39391
    9 CONTINUE
      FZH(J) = FZH(J)+PM1*FYH(J)*CTNDR
      IF (IMT.EQ.2) GO TO 12
C     CALC OF FORCE ON VENTRAL FINS
      VDS = DS-VX*THETA+VSPAN*VCOS
      IF (VDS.LE.0.) GO TO 10
      IF (VAREA.LE.0.) GO TO 10
      VWSPN = AMIN1(VSPAN,VDS/VCOS)
      VASPR = VWSPN/VCHORD
      VAREA = VWSPN*VCHORD
      VH = V+VX*R-VZ*P
      VV = W-VX*Q+PM1*VY*P+U*THETA
      VPHI = PHI+PM1*VANGLE
      VVTOL = SQRT(VV*VV+VH*VH)
      IF (VVTOL.EQ.0.0) GO TO 10
      VVNOR = COS(-ATAN2(VV,VH)+VPHI)*VVTOL
      VCLA = 2.*PI*VASPR/(VASPR+3.)
      ENDFAC = (1.+(VDS-VSPAN*VCOS)/VDS)**2
      ENDFAC = 1.0
      VFN = VCLA*(-VVNOR/U)*VAREA*(U*U+V*V)*HRHO
      VFN = VFN*ENDFAC
      VFYD = -HRHO*CDSW*VH*ABS(VH)*VAREA*COS(VPHI)
```

```
      VFY(J)  = VFN*COS(VPHI)+VFYD
      VFZ(J)  = VFN*SIN(VPHI)
      GO TO 11
   10 VFY(J)  = 0.0
      VFZ(J)  = 0.
      VVNOR = 0.0
      FXV = 0.0
   11 CONTINUE
   12 CONTINUE
C
      IF (IMT.EQ.2) GO TO 14
C     TOTAL SIDEWALL FORCES AMD MOMENTS
      FX = FXH(1)+FXH(2)
      FY = FYH(1)+FYH(2)
      FZ = FZH(1)+FZH(2)
      FK = (FZH(2)-FZH(1))*YSW+FKD-FY*ZS
      FY = FY+FYD
      FM = FMH(1)+FMH(2)+ZS*FX
      FN = FND+FNH(1)+FNH(2)+(FXH(1)-FXH(2))*YSW
      IF (VAREA.LE.0.0) GO TO 13
C     DRAG FORCE ON FINS
      REY = U*VCHORD/ENU
      CFV = .427/(ALOG10(REY)-.407)**2.64
      PI8 = PI/8.
      CD = 2.*CFV+PI8*VTC*VTC*(1.+G*VSPAN/(U*U))+VCLA*(VVNOR/U)**2
      FXV = -2.*CD*VAREA*HRHO*U*U
   13 CONTINUE
      FYV = VFY(1)+VFY(2)
      FZV = VFZ(1)+VFZ(2)
      FKV = (VFZ(2)-VFZ(1))*VY-FYV*VZ
      FMV = -FZV*VX+FXV*VZ
      FNV = FYV*VX
      FX = FX+FXV
      FY = FY+FYV
      FZ = FZ+FZV
      FK = FK+FKV
      FKOLD = FK
      FM = FM+FMV
      FN = FN+FNV
C
C     ADD ROLL DAMPING DUE TO VERTICAL WAVE GENERATION
C
   14 CONTINUE
      DSS = Z+ZS-XSS*THETA
      ZOR1 = (SIGN(1.,DSS)+1.)/2.
      DSS = DSS*ZOR1
      DS = Z+ZS
      DSR = DS-(XREF-XS)*THETA
```

```
      ID = 1.+(DSR*12.-SDS)/DDS
      ID = MAXO(MINO(ID,NDS),1)
      DDSR = (ID-1)*DDS+SDS
      ID1 = MINO(ID+1,NDS)
      DID = (DSR*12.-DDSR)/DDS
      BC2 = AC2(1,ID,IP)
      BC2 = BC2+DID*(AC2(1,ID1,IP)-BC2)+DIP*(AC2(1,ID,IP1)-BC2+DID*(AC2(
     11,ID1,IP1)-AC2(1,ID,IP1)-AC2(1,ID1,IP)+BC2))
      FK = FK-16.*YSW*YSW*BC2*P/PI
      FZH(1) = FZH(1)+8.*YSW*BC2*P/PI
      FZH(2) = FZH(2)-8.*YSW*BC2*P/PI
      IF (ISIDWL.NE.ON) RETURN
      WRITE (6,17) ((GAP(I,J),J=1,11),I=1,2),((DSW(I,J),J=1,11),I=1,2),F
     1X,FY,FZ,FK,FM,FN
      RETURN
C
   15 FORMAT (/10X,'WATER CONTACT WITH TOP OF BUBBLE CHAMBER AT ',
     1  F7.2,'FT.     TIME=',F7.2,'SEC.     IMMERSION=',F7.2,'FT.')
   16 FORMAT ('(T)',F10.5,11(F8.5),/,'(G)',F10.5,11(F8.5))
   17 FORMAT (/10X'SIDEWALL'/' GAP (FT.) (STERN TO BOW)'/' PORT SIDEWALL
     1' /11F10.5/' STBD SIDEWALL'/11F10.5/' IMMERSION DEPTH (FT.) (STERN
     2 TO BOW)'/' PORT SIDEWALL'/11F10.5/' STBD SIDEWALL'/11F10.5/10X
     3  'SIDEWL FX,FY,FZ,FK,FM,FN'/6E15.4)
      END
```

```
C
      SUBROUTINE STNSL
      INTEGER ON
      COMMON /AIR/ PINF,RHOINF,GAM
      COMMON /CONST/ PI,RAD,UO
      COMMON /FORSS/ FX,FY,FZ,FK,FM,FN,QL,FMS
      COMMON /GEOM/ WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNCM,DELS(4,
     110),XCP,ZCP
      COMMON /GEOMSS/ DETADX(11),DETADT(11),ARM1S(10),DFSS(10),TSKIS(10)
     1,ARM2S(10)
      COMMON /KSWTCH/ ITHRST
      COMMON /LEAKER/ ALEAK,CFSS
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AM
     1I(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,I
     1RUD,IPROP,IAEROD,IRHS
      COMMON /SOFTSS/ XLF,PSS,SINTH,COSTH,XSS,ZSS,DELYSS,DPSS,ELMAXS,YAV
     1GS(10)
      COMMON /STSLR/ CPHI,CPHID
      COMMON /VALOLD/ YOLD(20)
      COMMON /VARBLE/ VAL(40)
      COMMON /WAVE/ ETA(4,11),AW(10),OMEGA(10),DVOLW,NWAVE,BETA,FXWAV,FY
     1WAV,FZWAV,FKWAV,FMWAV,FNWAV,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PB
     2BAR
      EQUIVALENCE (VAL(1),TIME), (VAL(2),U), (VAL(3),V), (VAL(4),W), (VA
     1L(5),P), (VAL(6),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VA
     2L(10),Z), (VAL(11),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI)
     3, (VAL(24),PB)
      DIMENSION GAP(11), ELSKI(11)
      DATA ENU,UWSKI,CLSKI/1.28E-5,0.0,1.5708/
C
C
      DO 1 J=1,11
      GAP(J) = 0.0
      ELSKI(J) = 0.0
    1 CONTINUE
C
C
      ALSS = 0.0
      FX = 0.0
      FZ = 0.0
      FK = 0.0
      FM = 0.0
      FN = 0.0
      DELP = PSS-PB
      IF (DELP.LT.0.0) DELP=0.0
      PBAR = PB-PINF
C     CALCULATE ELSKI HERE.
```

```
      SINDIF = SINTH-COSTH*THETA
      COSDIF = COSTH+SINTH*THETA
      X1 = XSS+ZSS*THETA-XLF*SINDIF
      Z1 = -Z-ZSS+XSS*THETA-XLF*COSDIF
C     CALCULATE GAP HERE.
      N = NSTA(4)
C
C
      DO 2 K=1,N
      ELSKI(K) = (ETA(4,K)-DETADX(K)*(XX(4,K)-X1)-Z1)+YY(4,K)*PHI
      GAP(K) = -ELSKI(K)
      IF (GAP(K).LT.0.0) GAP(K)=0.0
    2 CONTINUE
C
C
      N = NSTA(4)-1
C
C
      DO 5 J=1,N
      ELSKIA = (ELSKI(J+1)+ELSKI(J))/2.
      IF (ELSKIA.LE.0.0) GO TO 3
      IF (ELSKIA.GT.ELMAXS) ELSKIA=ELMAXS
      ARM1S(J) = XX(4,J)+ELSKIA/2.
      ARM2S(J) = ZS-ELSKIA
      DFSS(J) = -DELP*ELSKIA*DELYSS
      ARG = .5*RHO*U*U*ELSKIA*DELYSS
      RESKI = U*ELSKIA/ENU
      CDTSKI = .427/(ALOG10(RESKI)-.407)**2.64
      TSKIS(J) = -ARG*CDTSKI
      GO TO 4
    3 DFSS(J) = 0.0
      TSKIS(J) = 0.0
    4 CONTINUE
      FX = FX+TSKIS(J)
      FZ = FZ+DFSS(J)
      FK = FK+DFSS(J)*YAVGS(J)
      FM = FM-DFSS(J)*ARM1S(J)+TSKIS(J)*ARM2S(J)
      FN = FN-TSKIS(J)*YAVGS(J)
      ALSS = ALSS+(GAP(J)+GAP(J+1))*DELYSS/2.0
    5 CONTINUE
C
C
      ALSS = ALSS+ALEAK
      QL = CFSS*ALSS*SQRT(2.*ABS(PBAR)/RHOINF)*SIGN(1.,PBAR)
      IF (ISTNSL.NE.ON) RETURN
      WRITE (6,6) GAP,ELSKI,FX,FY,FZ,FK,FM,FN
      RETURN
C
```

```
C
    6 FORMAT (//12H  STERN SEAL/26H  GAP (FT.) PORT TO STBD. /11E11.3/28
     1H  ELSKI (FT.) PORT TO STBD. /11E11.3/10X,23HSTNSL FX,FY,FZ,FK,FM,
     2FN/6E15.4)
      END
```

```
   IF (ABS(X)-.1) 1,1,2
1  T1 = X*(1.-X*X/10.0)/3.
   RETURN
2  T1 = (SIN(X)-X*COS(X))/(X*X)
   RETURN
   END
```

```
C
      FUNCTION T2 (X)
      IF (ABS(X)-.1) 1,1,2
    1 T2 = 1.-X*X/6.
      RETURN
    2 T2 = SIN(X)/X
      RETURN
      END
```

```
C
      SUBROUTINE WAVES (TIME)
      INTEGER ON
      COMMON /BMCO/ IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IY
      COMMON /CONST/ PI,RAD,U0
      COMMON /GEOM/ WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM,DELS(4,
     110),XCP,ZCP
      COMMON /GEOMBS/ DETABX(11),DETABT(11),ARM1B(10),ARM2B(10),DFBS(10)
     1,TSKIB(10)
      COMMON /GEOMSS/ DETADX(11),DETADT(11),ARM1S(10),DFSS(10),TSKIS(10)
     1,ARM2S(10)
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AM
     1I(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO
      COMMON /MWAVE/ FXW(2),FYW(2),FZW(2),FKW(2),FMW(2),FNW(2)
      COMMON /PLENUM/ XLBW,XBBW,ABW,BUBHGT
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,I
     1RUD,IPROP,IAEROD,IRHS
      COMMON /RISER/ AMPTC
      COMMON /SIDE/ FXSW,FYSW,FZSW,FKSW,FMSW,FNSW,ALSW,YSW,XLSW,CFSW,CDS
     1W,VAREA,VCHORD,VSPAN,VANGLE,VCOS,VX,VY,VZ,AVBMSW,DELX,VTC
      COMMON /VARBLE/ VAL(40)
      COMMON /WAVE/ ETA(4,11),AW(10),OMEGA(10),DVOLW,NWAVE,BETA,FXWAV,FY
     1WAV,FZWAV,FKWAV,FMWAV,FNWAV,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PB
     2BAR
      COMMON /WAVTAB/ NAL,DAL,SAL,NDS,DDS,SDS,NTH,DTH,STH,NBB,DBB,SBB,AC
     11(20,5,7),AC2(20,5,7),AC3(20,5,7),AC4(20,5,7),AC5(20,5,7),AC6(20,5
     2,7),AC7(20,5,7),AC0(20,5,7),AC00(20,5,7),AC8(20,5,7),AS1(20,5,7),A
     3S2(20,5,7),AS3(20,5,7),AS4(20,5,7),AS5(20,5,7),AS6(20,5,7),AS7(20,
     45,7),AS0(20,5,7),AS00(20,5,7),AS8(20,5,7),BB(36),XREF,RX
      DIMENSION WC0(2), WC00(2), WC1(2), WC2(2), WC3(2), WC4(2), WC5(2),
     1 WC6(2), WC7(2), WC8(2)
      DIMENSION WS0(2), WS00(2), WS1(2), WS2(2), WS3(2), WS4(2), WS5(2),
     1 WS6(2), WS7(2), WS8(2)
      EQUIVALENCE (VAL(2),U), (VAL(3),V), (VAL(4),W), (VAL(5),P), (VAL(6
     1),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VAL(10),Z), (VAL(
     211),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI), (VAL(24),PB)
      EQUIVALENCE (VAL(16),ETACG)
      IF (NWAVE.EQ.0) RETURN
      GAMMA = BETA-PSI
      SIGAM = SIN(GAMMA)
      COGAM = COS(GAMMA)
      FO = -X*COSBET-Y*SINBET
      DVOLW = 0.0
      ETACG = 0.0
      N = NSTA(3)
C
      DO 1 J=1,N
      DETABX(J) = 0.0
```

```
      1 CONTINUE
C
        N = NSTA(4)
C
        DO 2 J=1,N
        DETADX(J) = 0.0
      2 CONTINUE
C
C
        DO 3 J=1,4
        N = NSTA(J)
C
        DO 3 K=1,N
      3 ETA(J,K) = 0.0
C
C
        DO 4 J=1,2
        FXW(J) = 0.0
        FYW(J) = 0.0
        FZW(J) = 0.0
        FKW(J) = 0.0
        FMW(J) = 0.0
        FNW(J) = 0.0
      4 CONTINUE
C
        XSS = -XS
        IF (IMT.EQ.2) XSS = XMI(IX)
        IP = 1+(THEBAR*RAD-STH)/DTH
        IP = MAXO(MINO(IP,NTH),1)
        IP1 = MINO(IP+1,NTH)
        DTHETA = (IP-1)*DTH+STH
        DIP = (THETA*RAD-DTHETA)/DTH
C       TIME RISE FACTOR FOR WAVE AMPLITUDE
        AMPFAC = 1.-EXP(-TIME/AMPTC)
C
        DO 11 I=1,NWAVE
        OM1 = OMEGA(I)
        OM2 = OM1*OM1
        XWK = OM2/G
        AA = AW(I)*AMPFAC
        FT = OM1*TIME+XWK*FO
        AL = XWK*COGAM
        IAA = 1+(ABS(AL)-SAL)/DAL
        IAA = MAXO(MINO(IAA,NAL),1)
        IAA1 = MINO(IAA+1,NAL)
        DAA = (IAA-1)*DAL+SAL
        DIA = (ABS(AL)-DAA)/DAL
        SALP = SIGN(1.,AL)
```

```
C     WAVE FORCES AND MOMENTS ON THE SIDEWALLS
C
      DO 7 J=1,2
      YLSW = (2*J-3)*YSW
      WE = FT+XWK*SIGAM*YLSW
      ST = SIN(WE)
      CT = COS(WE)
      DS = ZBAR+ZS+YLSW*PHIBAR
      DSR = DS-(XREF-XS)*THEBAR
      ID = 1.+(DSR*12.-SDS)/DDS
      ID = MAXO(MINO(ID,NDS),1)
      DDSR = (ID-1)*DDS+SDS
      DID = (DSR*12.-DDSR)/DDS
      ID1 = MINO(ID+1,NDS)
      DSS = DS-XSS*THEBAR
      ZOR1 = (SIGN(1.,DSS)+1.)/2.
      DSS = DSS*ZOR1
      IDSS = 1.5+(DSS-SBB)/DBB
      IDSS = MINO(NBB,IDSS)
      BS = BB(IDSS)
      CK = COS(XWK*COGAM*XSS)
      A33S = (RHO*PI*BS**2)/8.
      SK = SIN(XWK*COGAM*XSS)
      A22S = (RHO*.4*PI*DSS**2)/2.
      A42S = 0.0
C     INTERPOLATION OF WAVE TABLES
      K = 1
      L = IAA
    5 CONTINUE
      BCO = ACO(L,ID,IP)
      BCOO = ACOO(L,ID,IP)
      BC1 = AC1(L,ID,IP)
      BC2 = AC2(L,ID,IP)
      BC3 = AC3(L,ID,IP)
      BC4 = AC4(L,ID,IP)
      BC5 = AC5(L,ID,IP)
      BC6 = AC6(L,ID,IP)
      BC7 = AC7(L,ID,IP)
      BC8 = AC8(L,ID,IP)
      BSO = ASO(L,ID,IP)
      BSOO = ASOO(L,ID,IP)
      BS1 = AS1(L,ID,IP)
      BS2 = AS2(L,ID,IP)
      BS3 = AS3(L,ID,IP)
      BS4 = AS4(L,ID,IP)
      BS5 = AS5(L,ID,IP)
      BS6 = AS6(L,ID,IP)
      BS7 = AS7(L,ID,IP)
```

```
      BS8 = AS8(L,ID,IP)
      WCO(K) = BCO+DID*(ACO(L,ID1,IP)-BCO)+DIP*(ACO(L,ID,IP1)-BCO+DID*(A
     1CO(L,ID1,IP1)-ACO(L,ID,IP1)-ACO(L,ID1,IP)+BCO))
      WCOO(K) = BCOO+DID*(ACOO(L,ID1,IP)-BCOO)+DIP*(ACOO(L,ID,IP1)-BCOO+
     1DID*(ACOO(L,ID1,IP1)-ACOO(L,ID,IP1)-ACOO(L,ID1,IP)+BCOO))
      WC1(K) = BC1+DID*(AC1(L,ID1,IP)-BC1)+DIP*(AC1(L,ID,IP1)-BC1+DID*(A
     1C1(L,ID1,IP1)-AC1(L,ID,IP1)-AC1(L,ID1,IP)+BC1))
      WC2(K) = BC2+DID*(AC2(L,ID1,IP)-BC2)+DIP*(AC2(L,ID,IP1)-BC2+DID*(A
     1C2(L,ID1,IP1)-AC2(L,ID,IP1)-AC2(L,ID1,IP)+BC2))
      WC3(K) = BC3+DID*(AC3(L,ID1,IP)-BC3)+DIP*(AC3(L,ID,IP1)-BC3+DID*(A
     1C3(L,ID1,IP1)-AC3(L,ID,IP1)-AC3(L,ID1,IP)+BC3))
      WC4(K) = BC4+DID*(AC4(L,ID1,IP)-BC4)+DIP*(AC4(L,ID,IP1)-BC4+DID*(A
     1C4(L,ID1,IP1)-AC4(L,ID,IP1)-AC4(L,ID1,IP)+BC4))
      WC5(K) = BC5+DID*(AC5(L,ID1,IP)-BC5)+DIP*(AC5(L,ID,IP1)-BC5+DID*(A
     1C5(L,ID1,IP1)-AC5(L,ID,IP1)-AC5(L,ID1,IP)+BC5))
      WC6(K) = BC6+DID*(AC6(L,ID1,IP)-BC6)+DIP*(AC6(L,ID,IP1)-BC6+DID*(A
     1C6(L,ID1,IP1)-AC6(L,ID,IP1)-AC6(L,ID1,IP)+BC6))
      WC7(K) = BC7+DID*(AC7(L,ID1,IP)-BC7)+DIP*(AC7(L,ID,IP1)-BC7+DID*(A
     1C7(L,ID1,IP1)-AC7(L,ID,IP1)-AC7(L,ID1,IP)+BC7))
      WC8(K) = BC8+DID*(AC8(L,ID1,IP)-BC8)+DIP*(AC8(L,ID,IP1)-BC8+DID*(A
     1C8(L,ID1,IP1)-AC8(L,ID,IP1)-AC8(L,ID1,IP)+BC8))
      WSO(K) = BSO+DID*(ASO(L,ID1,IP)-BSO)+DIP*(ASO(L,ID,IP1)-BSO+DID*(A
     1SO(L,ID1,IP1)-ASO(L,ID,IP1)-ASO(L,ID1,IP)+BSO))
      WSOO(K) = BSOO+DID*(ASOO(L,ID1,IP)-BSOO)+DIP*(ASOO(L,ID,IP1)-BSOO+
     1DID*(ASOO(L,ID1,IP1)-ASOO(L,ID,IP1)-ASOO(L,ID1,IP)+BSOO))
      WS1(K) = BS1+DID*(AS1(L,ID1,IP)-BS1)+DIP*(AS1(L,ID,IP1)-BS1+DID*(A
     1S1(L,ID1,IP1)-AS1(L,ID,IP1)-AS1(L,ID1,IP)+BS1))
      WS2(K) = BS2+DID*(AS2(L,ID1,IP)-BS2)+DIP*(AS2(L,ID,IP1)-BS2+DID*(A
     1S2(L,ID1,IP1)-AS2(L,ID,IP1)-AS2(L,ID1,IP)+BS2))
      WS3(K) = BS3+DID*(AS3(L,ID1,IP)-BS3)+DIP*(AS3(L,ID,IP1)-BS3+DID*(A
     1S3(L,ID1,IP1)-AS3(L,ID,IP1)-AS3(L,ID1,IP)+BS3))
      WS4(K) = BS4+DID*(AS4(L,ID1,IP)-BS4)+DIP*(AS4(L,ID,IP1)-BS4+DID*(A
     1S4(L,ID1,IP1)-AS4(L,ID,IP1)-AS4(L,ID1,IP)+BS4))
      WS5(K) = BS5+DID*(AS5(L,ID1,IP)-BS5)+DIP*(AS5(L,ID,IP1)-BS5+DID*(A
     1S5(L,ID1,IP1)-AS5(L,ID,IP1)-AS5(L,ID1,IP)+BS5))
      WS6(K) = BS6+DID*(AS6(L,ID1,IP)-BS6)+DIP*(AS6(L,ID,IP1)-BS6+DID*(A
     1S6(L,ID1,IP1)-AS6(L,ID,IP1)-AS6(L,ID1,IP)+BS6))
      WS7(K) = BS7+DID*(AS7(L,ID1,IP)-BS7)+DIP*(AS7(L,ID,IP1)-BS7+DID*(A
     1S7(L,ID1,IP1)-AS7(L,ID,IP1)-AS7(L,ID1,IP)+BS7))
      WS8(K) = BS8+DID*(AS8(L,ID1,IP)-BS8)+DIP*(AS8(L,ID,IP1)-BS8+DID*(A
     1S8(L,ID1,IP1)-AS8(L,ID,IP1)-AS8(L,ID1,IP)+BS8))
      IF (K.EQ.2) GO TO 6
      K = 2
      L = IAA1
      GO TO 5
    6 BCO = WCO(1)+DIA*(WCO(2)-WCO(1))
      BCOO = WCOO(1)+DIA*(WCOO(2)-WCOO(1))
      BC1 = WC1(1)+DIA*(WC1(2)-WC1(1))
```

```
      BC2 = WC2(1)+DIA*(WC2(2)-WC2(1))                                   WAV 1920
      BC3 = WC3(1)+DIA*(WC3(2)-WC3(1))                                   WAV 1930
      BC4 = WC4(1)+DIA*(WC4(2)-WC4(1))                                   WAV 1940
      BC5 = WC5(1)+DIA*(WC5(2)-WC5(1))                                   WAV 1950
      BC6 = WC6(1)+DIA*(WC6(2)-WC6(1))                                   WAV 1960
      BC7 = WC7(1)+DIA*(WC7(2)-WC7(1))                                   WAV 1970
      BC8 = WC8(1)+DIA*(WC8(2)-WC8(1))                                   WAV 1980
      BS0 = (WS0(1)+DIA*(WS0(2)-WS0(1)))*SALP                            WAV 1990
      BS00 =  (WS00(1)+DIA*(WS00(2)-WS00(1)))*SALP                       WAV 2000
      BS1 = (WS1(1)+DIA*(WS1(2)-WS1(1)))*SALP                            WAV 2010
      BS2 = (WS2(1)+DIA*(WS2(2)-WS2(1)))*SALP                            WAV 2020
      BS3 = (WS3(1)+DIA*(WS3(2)-WS3(1)))*SALP                            WAV 2030
      BS4 = (WS4(1)+DIA*(WS4(2)-WS4(1)))*SALP                            WAV 2040
      BS5 = (WS5(1)+DIA*(WS5(2)-WS5(1)))*SALP                            WAV 2050
      BS6 = (WS6(1)+DIA*(WS6(2)-WS6(1)))*SALP                            WAV 2060
      BS7 = (WS7(1)+DIA*(WS7(2)-WS7(1)))*SALP                            WAV 2070
      BS8 = (WS8(1)+DIA*(WS8(2)-WS8(1)))*SALP                            WAV 2080
C     SHIFT MOMENT CENTER FROM XREF TO C.G.                              WAV 2090
      BC00 = BC00-(XS-XREF)*BC0                                          WAV 2100
      BC3 = BC3-(XS-XREF)*BC1                                            WAV 2110
      BC4 = BC4-(XS-XREF)*BC2                                            WAV 2120
      BC6 = BC6-(XS-XREF)*BC5                                            WAV 2130
      BS00 = BS00-(XS-XREF)*BS0                                          WAV 2140
      BS3 = BS3-(XS-XREF)*BS1                                            WAV 2150
      BS4 = BS4-(XS-XREF)*BS2                                            WAV 2160
      BS6 = BS6-(XS-XREF)*BS5                                            WAV 2170
C     CALCULATE WAVE FORCES AND MOMENTS                                  WAV 2180
      FZC = BS1-XWK*G*(BS2+BS0)-U*OM1*(-A33S*CK-AL*BS2)                  WAV 2190
      FZS = BC1-XWK*G*(BC2+BC0)+U*OM1*(-A33S*SK+AL*BC2)                  WAV 2200
      FMC = BS3-XWK*G*(BS4+BS00)-U*OM1*(-A33S*XSS*CK-BC2-AL*BS4)         WAV 2210
      FMS = BC3-XWK*G*(BC4+BC00)+U*OM1*(-A33S*XSS*SK-BS2+AL*BC4)         WAV 2220
      FYC = XWK*G*(BC5+BC0)-U*OM1*(-A22S*SK+AL*BC5)                      WAV 2230
      FYS = -XWK*G*(BS5+BS0)-U*OM1*(-A22S*CK-AL*BS5)                     WAV 2240
      FNC = XWK*G*(BC6+BC00)-U*OM1*(-A22S*XSS*SK-BS5+AL*BC6)             WAV 2250
      FNS = -XWK*G*(BS6+BS00)-U*OM1*(-A22S*XSS*CK-BC5-AL*BS6)            WAV 2260
      FKC = XWK*G*(BC7-BC8)+U*OM1*(-A42S*SK+AL*BC8)                      WAV 2270
      FKS = -XWK*G*(BS7-BS8)+U*OM1*(-A42S*CK-AL*BS8)                     WAV 2280
      FZW(J) = FZW(J)-AA*(FZC*CT+FZS*ST)                                 WAV 2290
      FMW(J) = FMW(J)+AA*(FMC*CT+FMS*ST)                                 WAV 2300
      FYW(J) = FYW(J)-AA*(FYC*CT+FYS*ST)*SIGAM                           WAV 2310
      FNW(J) = FNW(J)-AA*(FNC*CT+FNS*ST)*SIGAM                           WAV 2320
      FKW(J) = FKW(J)-AA*(FKC*CT+FKS*ST)*SIGAM                           WAV 2330
      FXW(J) = FXW(J)-2.*AA*RHO*G*BS*DSS*SK*CT                           WAV 2340
    7 CONTINUE                                                           WAV 2350
C                                                                        WAV 2360
      IF (IMT.EQ.2) GO TO 11                                             WAV 2370
C     WAVE ELEVATION AROUND THE SIDEWALLS AND SEALS                      WAV 2380
C                                                                        WAV 2390
```

```
      DO 8 J=1,4
      N = NSTA(J)
C
      DO 8 K=1,N
      ETA(J,K) = ETA(J,K)+SIN(XWK*(-XX(J,K)*COGAM-YY(J,K)*SIGAM)+FT)*AA
    8 CONTINUE
C
      ETACG = ETACG+AA*SIN(FT)
      N = NSTA(3)
C
      DO 9 J=1,N
      ARG = AA*COS(XWK*(-XX(3,J)*COGAM)+FT)
      DETABX(J) = DETABX(J)-XWK*COGAM*ARG
    9 CONTINUE
C
      N = NSTA(4)
C
      DO 10 J=1,N
      ARG = AA*COS(XWK*(-XX(4,J)*COGAM)+FT)
      DETADX(J) = DETADX(J)-XWK*COGAM*ARG
   10 CONTINUE
C
C     WAVE PUMPING
      X1 = XWK*XLBW*COGAM/2.
      X2 = XWK*XBBW*SIGAM/2.
      FTT = FT-XWK*XCP*COGAM
      DVOLW = DVOLW+AA*ABW*T2(X1)*T2(X2)*SIN(FTT)
   11 CONTINUE
C
      IF (IMT.EQ.2) RETURN
C     TOTAL WAVE FORCES AND MOMENTS
      FXWAV = FXW(1)+FXW(2)
      FYWAV = FYW(1)+FYW(2)
      FZWAV = FZW(1)+FZW(2)
      FKWAV = FKW(1)+FKW(2)+(FZW(2)-FZW(1))*YSW+FYWAV*ZBAR
      FMWAV = FMW(1)+FMW(2)-FXWAV*ZBAR
      FNWAV = FNW(1)+FNW(2)+(FXW(1)-FXW(2))*YSW
      IF (IWAVES.NE.ON) RETURN
      WRITE (6,12) ((ETA(I,J),J=1,11),I=1,4),ETACG,DVOLW,FXWAV,FYWAV,FZW
     1AV,FKWAV,FMWAV,FNWAV
      RETURN
C
   12 FORMAT (/10X,5HWAVES/63H WAVE ELEVATIONS AT CRAFT STATIONS RELATIV
     1E TO CALM WATER (FT.)/14H PORT SIDEWALL/11F10.5/14H STBD SIDEWALL/
     211F10.5/9H BOW SEAL/11F10.5/11H STERN SEAL/11F10.5/25H WAVE ELEVAT
     3ION AT C.G. =F10.5,10X,43HPLENUM VOLUME LOST DUE TO WAVES (CU. FT.
     4) =F15.5/10X,23HWAVES FX,FY,FZ,FK,FM,FN/6E15.4)
      END
```

THE FOLLOWING IS A SAMPLE INPUT DECK USED FOR A TYPICAL RUN.
THIS DECK WILL CREATE A RUN OF TWENTY-FIVE SECONDS DURATION
IN SEA STATE 4 AT 40 KNOTS. IT WILL BE RUN WITH BOTH CONTROLS
IN OPERATION.

```
00101  0.0      25.        0.001       0.05        0.0
00102

00103
1202
  .0001   .0002      .000001   .0000001  .0001      .000001    .000000001.000000001
  .0001   .0001      .00001    .00001
00104
    1    1
00105
00201209999.313  33.092    7.092    1073780.002769405.003635907.00-99900.313
00301  11.0      11.0      5.0       5.0       72.0
00401   15.54     60.0       .7       1.28       1.36
00402  30.        3.0       3.0       15.0      14.875      -1.5       .075
00403  4.0        6.0
 30.       40.       60.       85.
 1.0       2.0       3.0       4.0       5.0       6.0
 778.15    379.63    281.95    189.66    114.31    14.34
 1318.43   641.49    475.98    319.90    192.67    24.10
 2776.13   1345.82   997.34    669.53    402.82    50.20
 4713.17   2279.22    1687.61  1132.02   680.62    84.60
00501 7.5        5.479     25.52      .90       55.5       26.        9.101
00601 53.07      .60       24.        3.75
00701 65.31      31.16                28.00     65.31      33.4       6.17
00702 .6
00801  -1.0     15.75      0.9       6281.14    3960.
00901  6.125     15.6      -1.5       3.0        1.4       6.375      .108
01001 63.15      31.65
01201  40.      0.46      13.99      92.8
01901 1.         1700.     17.        1.        1700.
 0.       33.       62.       87.       106.      118.      128.      133.
 137.     139.      141.      143.      146.      152.      160.      180.
 200.
1185.     1100.     1000.     900.      800.      700.      600.      500.
 400.     300.      100.      -50.      -95.      -145.     -175.     -220.
 -235.
01902 5.         1700.     16.        1.        1700.
 0.       28.       54.       76.       91.       104.      112.      118.
 120.     121.      122.      126.      133.      142.      160.      176.
 1195.    1100.     1000.     900.      800.      700.      600.      500.
 400.     0.        -50.      -100.     -150.     -180.     -220.     -240.
```

```
01903 2.        1870.      17.         1.         1870.
 0.       9.        42.        70.        94.        114.       127.       136.
 144.     147.      150.       151.       154.       160.       180.       200.
 218.
 1340.    1300.     1200.      1100.      1000.      900.       800.       700.
 600.     500.      400.       0.         -100.      -165.      -215.      -245.
 -260.
01101    8.        180.
0.560072  0.170611
0.694653  0.870252
0.861571  1.351048
1.068599  1.268786
1.325373  0.963507
1.643847  0.668865
2.038847  0.447041
2.528763  0.294032
01904     .65       16.        9.         2.         20.        0.         3.0
 OPTSBH=3.0 BOTH CONTROLS ON
018
SEA STATE 4 AHEAD 40 KNOTS BOTH CONTROLS ON
020
00000000
021
01030507081 23435
01020604171 83325
022
0701
0107010501120133013401350125
SEA STATE 4 AHEAD 40 KNOTS BOTH CONTROLS ON
013
014
```

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Thesis 158282
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